THE NICKEL BULLETIN

A SUMMARY OF CURRENT INFORMATION ON NICKEL

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THE CONSERVATION OF ALLOY STEELS

In our May issue we gave details of the steels covered by a recent Direction of the Minister of Supply. Since then there have been modifications to the exemptions and, furthermore, the data then published were based on preliminary information. In the light of later information, we therefore reprint the whole article with the latest corrections.

IN ORDER to conserve nickel and molybdenum, the Minister of Supply has issued a Direction restricting the use of these elements in certain forms of alloy steel. This Direction (effective June 2nd, 1952) prohibits:—

(1) conversion, by steelmakers, of alloy steel into machining bars or forgings (including drop forgings) up to 6-in. ruling section,
and

(2) supply, to steelmakers, of alloy steel for such conversion, unless
either
(*a*) (i) the steel contains no nickel or molybdenum; or
(ii) the steel contains less than certain specified amounts of nickel and of molybdenum, and the bar or forging complies with certain minimum tensile strength and ruling section requirements as shown in Table I,
or
(*b*) the use of a steel richer in nickel or molybdenum has been authorized by an Alloy Steel Assent issued by the Director, Alloy Steel Control, on behalf of the Minister of Supply.

The above restrictions *do not, however, apply*:—

(*a*) to alloy steels which are to be converted into products other than machining bars or forgings;
nor

(*b*) to an alloy steel—in any form whatsoever—which is in one or other of the following specified categories:—
Corrosion-resisting, heat-resisting or creep-resisting steels,
Nitriding steels,
Tool, die, spring, magnet or ball- or roller-bearing steels,
Steels to 'S' and 'DTD' Specifications, when subject to A.I.D. or A.R.B. inspection,
Induction-hardening steels,
Steels for gun components to Ministry of Supply Specification S.56, or to Admiralty Specification E.52, E.53 or E.54,
Steels to any Ministry of Supply I.F.V. Specification or to any Admiralty Specification containing a ballistic test standard,
Steels for armour-piercing projectiles or for torpedoes,
Steels for turbine blading,
Steels prepared as a drawn wire in coil.

Also, the above restrictions *do not apply* to alloy steels produced solely 'for export' or solely for conversion into a machining bar or forging which is itself solely 'for export' as such.

The Technical Committee of the Steel (Rearmament) Panel has made recommendations, and from time to time may make further recommendations, concerning steels to En specifications which are most suitable for use in complying with the above-mentioned Direction. Details of these recommended steels will be found in Tables II to V.

Table II shows the hardening and tempering steels which can be used without an Assent for given tensile ranges and diameters or ruling

Table I

Hardening and Tempering Alloy Steels

Maximum Content of		Minimum Tensile Strength	Minimum Ruling Section
Nickel %	Molybdenum %	t.s.i.	
1·00	0·25	45	Not limited
1·60	0·20		
1·80	0·35	55 60 65 70	4-in. 2½-in. 1⅞-in. Not limited
2·80	0·60	60 65 75	4-in. 2½-in. 1⅜-in.
4·30	0·30	100	Not limited if air hardened and tempered. 4-in. if heat-treated otherwise.

Carburizing Alloy Steels

Maximum Content of		Minimum Tensile Strength of Ultimate Product when heat-treated as a 1⅜-in. bar t.s.i.
Nickel %	Molybdenum %	
1·00	0·10	45
0·70	0·15	
1·25	0·10	55
1·50	0·15	65
2·00	0·20	75
2·20	0·25	85 (but when heat-treated at test-piece size)

Table II

Permitted Hardening and Tempering Steels for Sizes up to 6-in. (152 mm.) Ruling Section

Symbol	Tensile Range		Diameter of Ruling Section				
	t.s.i.	kg/mm²	in.: up to $\frac{7}{8}$ mm.: up to 22	$\frac{7}{8}$ to $1\frac{1}{8}$ 22 to 29	$1\frac{1}{8}$ to $2\frac{1}{2}$ 29 to 63	$2\frac{1}{2}$ to 4 63 to 102	4 to 6 102 to 152
R	45–55	71–87	En No. 15 18	En No. 15 18	En No. 15 18	En No. 18 100	En No. 100 111
S	50–60	79–95	15 18	18	18	100(*a*) 111	100(*a*) 111
T	55–65	87–102	18 100 111	18 100 111	100 111	110	24
U	60–70	95–110	100 111	100 111	100(*a*) 110	24	25(*e*) 29(*e*)
V	65–75	102–118	100 110	100 110	24	25(*e*) 26(*e*)	26(*e*)
W	70–80	110–126	110 24	110 24	24(*b*)	25(*e*) 26(*e*)	26(*e*)
X Y	75–85 80–90	118–134 126–142	24	24	25(*e*) 26(*e*)	26(*e*)	26(*e*)
Z	100 min.	157 min.	24 110(*c*) 111(*c*) 30(*d*, *e*)	24 110(*c*) 111(*c*) 30(*d*, *e*)	30(*d*, *e*) 25(*e*) 26(*e*)	26(*e*)	30(*e*)

(*a*) B.S. 970 quotes S properties on En 100 only up to 4 in. and U properties only up to $1\frac{1}{8}$ in.

(*b*) B.S. 970 quotes W properties on En 24 only up to $1\frac{1}{8}$ in.

(*c*) B.S. 970 does not quote 100 t.s.i. properties on En 100 or En 111. To attain 100 t.s.i. a higher carbon content (0·35-0·45 per cent.) is necessary for En 111.

(*d*) En 30 may be used up to $2\frac{1}{2}$ in. for air-hardening and tempering only.

(*e*) The molybdenum content of En 25, En 26 and En 29 must not exceed 0·60 per cent., and of En 30B must not exceed 0·30 per cent., without an Alloy Steel Assent.

Table III
Chemical Composition of Steels Listed in Table II

En No.	Type of Steel	Chemical Composition				
		C %	Mn %	Ni %	Cr %	Mo %
En 15	1·5% Mn	0·30-0·40	1·3-1·7	—	—	—
En 18	1% Cr	0·35-0·45	0·60-0·95	—	0·80-1·1	—
En 24	1½% Ni-Cr-Mo	0·35-0·45	0·45-0·70	1·3-1·8	0·90-1·4	0·20-0·35
En 25	2½% do. (medium-carbon)	0·27-0·35	0·50-0·70	2·3-2·8	0·50-0·80	0·40-0·70
En 26	do. do. (high-carbon)	0·36-0·44	do.	do.	do.	do.
En 29	3% Cr-Mo	0·15-0·35	0·65 max.	0·40 max.	2·5-3·5	0·30-0·70
En 30A	4¼% Ni-Cr	0·26-0·34	0·40-0·60	3·9-4·3	1·1-1·4	—
En 30B	4¼% Ni-Cr-Mo	do.	do.	do.	do.	0·2-0·4
En 100	Low Alloy	0·35-0·45	1·2-1·5	0·50-1·0	0·30-0·60	0·15-0·25
En 110	Low Ni-Cr-Mo	0·35-0·45	0·40-0·80	1·2-1·6	0·90-1·4	0·10-0·20
En 111	Low Ni-Cr	0·30-0·40	0·60-0·90	1·0-1·5	0·45-0·75	—

In all steels Si is 0·10-0·35 per cent., S is 0·05 max. per cent., P is 0·05 max. per cent.

Table IV
New 'Emergency' Case-Hardening Steels

En No.	Type of Steel	Chemical Composition					Mechanical Properties of Core		
		C %	Mn %	Ni %	Cr %	Mo %	M.S. t.s.i. min.	E% (3·54D) min.	Izod ft.-lb. min.
351	¾% Ni-Cr	0·20 max.	0·6-1·0	0·6-1·0	0·40-0·80	0·10 max.	45 (71)	18	30 (9·0)
352	1% Ni-Cr	0·22	0·5-1·0	0·85-1·25	0·60-1·0	do.	55 (87)	15	20 (7·0)
353	1¼% Ni-Cr	do.	do.	1·0-1·5	0·75-1·25	0·08-0·15	65 (102)	12	20 (7·0)
354	1¾% Ni-Cr-Mo	do.	do.	1·5-2·0	do.	0·10-0·20	75 (118)	12	20 (7·0)
355	2% Ni-Cr-Mo (Low Cr)	0·20 max.	0·40-0·70	1·80-2·20	1·40-1·80	0·15-0·25	85 (114)	12	25 (8·0)
361	'15' Carbon Low-Alloy	0·13-0·17	0·70-1·00	0·40-0·70	0·55-0·80	0·08-0·15	45 (71)	18	25 (8·0)
362	'20' Carbon Low-Alloy	0·18-0·23	do.	do.	do.	do.	55 (87)	15	15 (5·8)
363	'25' Carbon Low-Alloy	0·22-0·26	do.	do.	do.	do.	65* (102)	—	—

* Required only if steel is supplied on the basis of tensile strength.

N.B.—(1) Heat-treatment of the test-bar consists of: (*a*) Blank carburize at 880°-930°C.; (*b*) Refine at 850°-880°C.; (*c*) Harden in oil from 780°-820°C.; (*d*) Temper at not more than 200°C. for En 355 only.

(2) The test bars are of 1⅛-in. dia. (28·6 mm.) except in the case of En 355, when the test bar is machined to test-piece size (except for a grinding allowance, if required) prior to heat-treatment.

(3) When supplied in the 'softened' condition the Brinell Hardness of En 354 and En 355 must not exceed 277.

(4) Figures in ( ) refer to equivalent kg./mm² for the maximum stress and kg. m/cm² for the corresponding approximate Charpy (Mesnager notch) values.

sections, and Table III gives chemical compositions of such steels. Any permitted steel can, however, be up-graded, but *must not be* down-graded. The recommended case-hardening steels for specified tensile ranges are given in the two right-hand columns of Table V: steels which they replace are shown in the centre columns.

The new economy or emergency case-hardening steels, i.e., En 351-355 and En 361-363, are covered by Addendum No. 1, November 1951 to B.S. 970-1947, and to which the general clauses of B.S. 970 apply. Details of these steels will be found in Table IV.

The Ministry of Supply Direction defines an 'alloy steel' as any steel containing, by weight, one or more of the following elements in the percentages stated:—

Chromium	0·40 or more per cent.
Manganese	10·00 „ „ „
Molybdenum	0·10 „ „ „
Nickel	0·40 „ „ „
Tungsten	0·10 „ „ „
Vanadium	0·10 „ „ „

Table V

Alternative 'Standard' and 'Emergency' Case-Hardening Steels, Related to Mechanical Properties

Symbol	Tensile Range		Impact		'Standard' Steels B.S. 970		'Emergency' Steels permitted by the Direction	
	t.s.i.	kg/mm²	Izod ft.-lb.	Charpy Value* kg. m/cm²	En No.	Type	En No.	Type
R	45-55	71-87	40	11	33	3% Ni		
			40	11	34	2% Ni-Mo (lower C)		
			30	9			351	¾% Ni-Cr
			25	8			361	'15' C, Low Alloy
T	55-65	87- 102	25	8	35	2% Ni-Mo (higher C)		
			35	10	36T	3% Ni-Cr		
			35	10	325	Low Ni-Cr-Mo		
			20	7			352	1% Ni-Cr
			15	5·8			362	'20' C, Low Alloy
V	65-75	102-118	30	9	36V	3% Ni-Cr		
			30	9	38	5% Ni		
			20	7			353	1¼% Ni-Cr
			—	—			363	'25' C, Low Alloy
X	75-85	118-134	20	7	—	—	354	1¾% Ni-Cr-Mo
	85 min.	134 min.	25	8	39A	4¼% Ni-Cr		
	Heat-treated at test-piece size		25	8	39B	4¼% Ni-Cr-Mo		
			25	8	320	2% Ni-Cr-Mo (high Cr)	320	2% Ni-Cr-Mo (high Cr)
			25	8			355	2% Ni-Cr-Mo (low Cr)

* The Charpy (Mesnager Notch) values are approximately equivalent to the Izod values.

ABSTRACTS OF CURRENT PUBLISHED INFORMATION ON NICKEL AND ITS ALLOYS

GENERAL

Metallurgical Research in Canada

'Metallurgical Research in Canada: a Symposium.' *Canad. Mining and Metallurgical Bull.*, 1952, vol. 45, Apr., pp. 217-23.

This symposium, held during the 1951 Annual General Meeting of the Canadian Institute of Mining and Metallurgy, was designed to assemble data relating to projects under investigation, and the facilities employed at the various metallurgical research laboratories in Canada. In this report of the symposium, excerpts have been selected from the papers, giving the main points of interest: the scope of the individual papers is indicated below:—

J. CONVEY: 'High-Temperature Alloys.'
A condensed account of the testing facilities available in the various laboratories investigating titanium-base and high-nickel alloys for high-temperature service. The main development in the nickel-containing materials has been 'Kinsalloy' (nickel 70, molybdenum 22, aluminium 8, per cent.), and the study of modified alloys of this type requiring less molybdenum, or, preferably, molybdenum-free.

O. W. ELLIS: 'Iron and Steel.'
Review of work in progress under Government auspices, in the universities and under industrial sponsorship.

R. H. RIMMER: 'Light Alloys.'
Report of work in hand on magnesium, aluminium, titanium and their alloys.

B. CHALMERS: 'Research at the Universities.'
Discussion of chemical- and physical-metallurgy projects being studied.

R. C. BELL and H. R. BANKS: 'Lead, Zinc and Gold Metallurgy.'

L. C. RENZONI: 'Copper, Nickel and Cobalt.'
Account of some of the main activities of companies working on nickel- and cobalt-extraction processes, with emphasis on the extent to which intensive research carried out under their auspices is aiding development of improved methods.

Diamond Pyramid Hardness Testing: Tentative Standard

AMER. SOC. TESTING MATERIALS: 'Proposed Tentative Method of Test for Diamond Pyramid Hardness of Metallic Materials.' Contained in Report of A.S.T.M. Committee E-1 on Methods of Testing; *A.S.T.M. Preprint* 50, June, 1952, pp. 16-21.

Covering apparatus, test specimens, test procedure, measurement of impression, calibration of apparatus, and table showing diamond pyramid hardness numbers corresponding to impressions of given dimensions.

Mechanical Testing of Nickel-Alloy and Other Structural Steels

See abstract on p. 211.

Test for Determination of Relative Thermionic Emissive Properties of Metals

See abstract on p. 198.

Extrusion of Nickel Alloys and Other Materials: Recent Developments

See abstract on pp. 218 and 219.

Surface-Area Measurements on Nickel Catalyst and Powder by Fatty-Acid Adsorption Method

See abstract on p. 198.

NICKEL

Converter Practice for Nickel Matte

C. C. DOWNIE: 'Researches on Nickel Converter Practice.' *Mining Jnl.*, 1952, vol. 239, July 4, pp. 13-14.

The writer draws attention to differences in practice requisite for successful treatment of matte produced from (*a*) sulphide, and (*b*) garnierite ores. Details are given of various cycles of converter practice normally used for the respective grades of matte, including a comparison of procedures for handling of nickel and of cupro-nickel mattes. The final section of the article contains a short discussion of electrically heated converters.

Metallurgical Research in Canada

See abstract on this page.

Extraction of Nickel, Cobalt and Copper by Chemical Methods

'New Chemical Method Recovers Nickel, Cobalt, Copper Metal.' *Jnl. of Metals*, 1952, vol. 4, June, pp. 589-91.

Short notes, in somewhat general terms, on methods developed by Chemical Construction Corporation, for extraction of the metals named from mill concentrates or metal scrap. 'Refiners using the new process will prepare ore concentrates by standard flotation methods, introduce the concentrate as a slurry into an autoclave along with water and an acid or ammonia. From the resulting leach solution, recovery of individual metals is made by use of suitable reducing agents. By varying conditions during treatment, different metals in the ore are produced separately as pure powders, which may be pressed into forms

ready to market, or, in the case of copper, extruded as rods or pipe. By manipulating the variables during reduction, selective separation of nickel, and/or cobalt, and/or copper, can be made simultaneously. The separation is a continuous operation.' The article includes a hypothetical flow sheet for simultaneous recovery of the three metals, and photographs illustrating operations involved in recovery of copper from copper scrap.

Elastic Constants of Nickel

J. R. NEIGHBOURS, F. W. BRATTEN and C. S. SMITH: 'The Elastic Constants of Nickel.' *Jnl. Applied Physics*, 1952, vol. 23, Apr., pp. 389-93.

Elastic constants of nickel were determined by the pulsed ultrasonic method. Wave-velocity measurements on four nickel single crystals of general orientation which were magnetically saturated were combined by the approximation method, leading to values of the elastic constants $C_{11}=2\cdot53$, $C_{12}=1\cdot52$, $C_{44}=1\cdot24$, all in units of 10^{12} dyne cm^{-2}. The authors' results are compared with measurements made by other investigators, using different methods.

Effect of Temperature on Mechanical and Physical Properties of High-Purity Nickel

W. D. JENKINS and T. C. DIGGES: 'Effect of Temperature on the Tensile Properties of High-Purity Nickel.' *Jnl. Research Nat. Bur. Standards*, 1952, vol. 48, Apr., pp. 313-21; R.P. 2317.

The tests described are part of a comprehensive investigation of the rheological behaviour, and the tensile and creep properties, of high-purity nickel, high-purity copper, and alloys of the two metals. Results of creep tests at 110°, 250° and 300°F. (43°, 121° and 149°C.) on high-purity O.F.H.C. copper, and of short-time tensile tests at temperatures in the range −320° to +212°F. (−196° to +100°C.) on copper, nickel, and copper-nickel alloys in the annealed condition have been presented in earlier papers (*ibid.*, 1950, vol. 45, p. 153; 1951, vol. 47, p. 272; N.B.S. Circular 520, 1952).

Additional short-time tensile tests have now been made on the same lot of high-purity nickel as was used in the earlier study, and the results of these tests, together with a recapitulation of data previously published on the nickel, are recorded in the present paper. The analysis given is as follows:—nickel 99·85, copper 0·009, iron 0·04, manganese 0·03, silicon 0·11, carbon 0·007, sulphur 0·002, oxygen 0·002, nitrogen 0·001, hydrogen 0·002, per cent. Tension tests in the range −320° to +1500°F. (−196° to +815°C.) were made on material from bar in the annealed condition. The results are shown in a series of curves indicating effect of temperature on tensile and yield strengths, and on ductility: the relations of strength to true strain and of plastic deformation to hardness are also discussed. The structure of fractured cross-sections of specimens tested in tension at various temperatures are illustrated.

The general trend was for yield and tensile strengths and ductility at maximum load to decrease, and reduction of area (at complete fracture) to increase, with rise in temperature of test. Elongation at complete fracture reached a minimum at about 500°F. (260°C.). Irregularities were, however, observed in the trends of some of the tensile properties/temperature relationships at temperatures in the ranges of 80°-300°F. (27°-150°C.), and 500°-700°F. (260°-370°C.). The evidence obtained from the tests indicated that strain-ageing occurred at 80°-300°F. (27°-150°C.) and that recrystallization and recovery predominated in specimens fractured at 1200° or 1500°F. (648° or 815°C.).

Effect of Prior Strain at Low Temperatures on Room-Temperature Properties of Nickel and Nickel Silver

W. C. ELLIS and E. S. GREINER: 'Effect of Prior Strain at Low Temperatures on the Properties of Some Close-packed Metals at Room Temperature.' *Jnl. of Metals*, 1952, vol. 4, June, *Trans. Amer. Inst. Mining and Metallurgical Engineers*, pp. 648-50; T.P. 3253E.

Since the experimental findings reported below are interpreted from the point of view outlined by the authors at the beginning of the paper, their introduction is given verbatim:

'When metallic materials are deformed plastically, the process may be considered as one in which hardening and recovery occur simultaneously. The net hardening is that produced by deformation in the absence of recovery, lessened by recovery during and immediately following deformation. Strain hardening takes place through movements of large groups of atoms acting to a degree as an entity. A complex microstress system is developed. Recovery is a diffusive-type process involving single atoms or, at most, only a few atoms in concerted action. This is accompanied by elastic strain relaxation. Recovery is strongly temperature-dependent. The driving energy for the process resides in thermal fluctuations of the atoms, augmented by the energy of the stress field producing the deformation, and by that produced by the deformation. At very low temperatures recovery is essentially absent, or very small. At high temperatures in the hot-working range, recovery is so rapid that deformation results in no appreciable net hardening.

'The interplay of strain-hardening and recovery results in differing end structures, depending on the temperature and the strain rate of the process. For example, there is a prominent difference in the spacing of the slip markings and in the detail of X-ray diffraction patterns. High temperatures and slow strain rates favor a wide spacing of slip markings and sharp reflections. This suggests that change in rate of the recovery concurrent with deformation modifies to a degree the manner of the deformation. Different slip systems may operate. For very slow rates, the mechanism may, as has been suggested, differ from that of 'classical slip'.'

Electrical conductivity is a sensitive indicator of the state of strain in a material, and was therefore used in this investigation. The materials studied, in wire form, were: O.F.H.C. copper, high-purity and 2S-grade aluminium, and A (commercial grade) nickel. Wire, annealed, and initially 0·050 in. diameter, was drawn through diamond dies in a holder maintained

at 25°, −75° or −195°C.: conditions other than temperature were kept constant. Electrical resistivity at 20°C. was measured for the wire as produced by drawing in each of the conditions described, the measurements being made as quickly as possible after drawing, in order to minimize possible room-temperature recoverv.

Effect of temperature of drawing was most pronounced for copper, e.g., drawing to 80 per cent. reduction at 25°C. increased the resistivity by about 2 per cent., while drawing to the same reduction at −195°C. caused an increase of 6 per cent. The effect of drawing for the two grades of aluminium was similar to that observed for copper, but of less intensity. For nickel erratic results were obtained, and no sustained difference in trend in resistivity change was found on drawing at 25° and −195°C.

The resistivity studies were supplemented by investigation of the effect, on strength properties, of drawing wire and rolling sheet at low temperatures. Low-temperature drawing produced an increase in the flow stress for all three materials, and the room-temperature strength increased, in nickel, as well as in copper and aluminium. The relevant figures for nickel are: drawn to 52 per cent. reduction:—(1) drawn at 25°C., 124,000 p.s.i. (55·5 tons per sq. in.); (2) drawn at −195°C., 148,000 p.s.i. (66·0 tons per sq. in.). Further results presented relate to various materials rolled at 25° and at −195°C. In aluminium, copper, brass, phosphor bronze and nickel silver, sub-zero rolling produced large increases in tensile strength, yield strength, ductility and hardness. Proportional limit and modulus of elasticity were not greatly affected, but tended to be slightly lowered by the low-temperature rolling.

The authors point out that in materials in which lattice scattering predominates, electrical conductivity is decreased to a greater degree as the temperature of deformation is lowered. These effects are attributed to a decrease in simultaneous recovery during deformation as the temperature is lowered. Recovery is described as involving single atoms or small groups, and as being highly temperature-dependent.

Hardness Conversion Table for Nickel and High-Nickel Alloys

See abstract on p. 201.

Annealing and Pickling of Nickel and Nickel Alloys

See abstract on p. 202.

Stress in Evaporated Nickel Films

E. K. HALTEMAN: 'Electron Diffraction Evidence for the Existence of Microstress in Evaporated Metal Films.' *Jnl. Applied Physics*, 1952, vol. 23, Jan., pp. 150-1.

Line broadening in electron-diffraction powder patterns was investigated on nickel films evaporated at a high rate of deposition and under less than 2×10^{-5} mm. pressure, in order to reduce contamination by foreign gas molecules. The pure diffraction broadening was found to vary with the Bragg angle, in accordance with a microstress theory of broadening, rather than with a particle-size mechanism. The Fourier transform of the pure diffraction broadening was also found to be in agreement with a microstress mechanism.

Magnetic Properties of Nickel and Nickel Alloys

See abstract on p. 204.

Thermal Conductivity of Nickel and Nickel Alloys at High Temperature

See abstract on p. 216.

Nickel-containing Electrical-Resistance Materials

See abstract on p. 202.

Friction Studies on Nickel and Nickel Alloys

See abstract on p. 221.

Sulphur Poisoning of Nickel Catalysts: 'Sulphur-Active' Catalysts

C. H. RIESZ, H. A. DIRKSEN and W. J. KIRKPATRICK: 'Sulfur Poisoning of Nickel Catalysts. The Effects of Sulfur Composition, Sulfur Concentration and Rates of Natural Gasoline Feed upon Conversion Efficiency and Catalyst Life of a Nickel Cracking Catalyst, and a Brief Study of Nickel Sulfide Catalysts for the Cracking of Natural Gas.' *Inst. Gas Technology, Research Bull.* 10, Sept., 1951; 23 pp.

Report of two phases of a programme of research being conducted by the Institute of Gas Technology, on Catalysts for Gaseous Reactions, covering:—

(1) Study of the effects of specific sulphur compounds, with and without process-air additions, upon the catalytic steam-gasification of natural gasoline into the blue gas equivalents, using a commercial nickel catalyst.

(2) Development of a 'sulphur-active' catalyst of nickel sulphide, for steam conversion of natural gas into carbon monoxide and hydrogen, such a catalyst requiring hydrogen sulphide in the reacting gases to maintain the catalyst in a sulphided state.

The following extracts from the report give the main points of interest and the conclusions drawn from the experiments made:—

(1) *Sulphur Poisoning* manifests itself in two distinct ways:—

(*a*) by accelerating the normal rates of carbon deposition on and within the catalyst granules;

(*b*) by lessening the completeness of the hydrocarbon conversion to carbon monoxide and hydrogen.

Criteria used for evaluating these effects are described and a table summarizes experimental data showing effect of type of sulphur on conversion efficiency and life of catalyst. The indications are that acceleration of the normal rates of carbon deposition by sulphur, and the sulphiding of active nickel by sulphur are two different reactions, the rates of which are independently affected by the chemical composition of the sulphur.

(2) *Effect of Air*, when admixed with the process steam, is always to lengthen the service life of the catalyst, by reducing the rate of accumulation of carbon. Effect of process air on conversion activity or efficiency of the catalyst, while usually beneficial, may in some circumstances be adverse.

(3) *Effect of Sulphur Concentration and Rates of Hydrocarbon Feed on Sulphur Poisoning*. While the chemical form of the sulphur appears to affect performance of the catalyst, with regard to operating life and efficiency, the magnitude of these effects may be considerably modified by choice of operating conditions (steam ratios, feed rates, operating temperatures and sulphur concentration). Typical examples of the effect of variation in conditions are given.

(4) *Regeneration of Nickel Catalysts*. The work reported confirmed previous experience in earlier stages of the research, showing that no permanent impairment of catalytic activity directly results from sulphur poisoning. It was found possible to re-use the same catalyst after repeated revivification, with no observable differences in its life or conversion activity. Correct control of conditions during revivification is important, since nickel catalysts can be seriously and permanently damaged by overheating, particularly in cases where appreciable amounts of carbon have accumulated.

(5) *Preference for Nickel Catalysts in Hydrocarbon Cracking*. Although claims have been made for the efficiency of alkali and alkaline-earth catalysts, laboratory tests in the research now reported indicate that such catalysts do not meet the operating requirements of American practice in the steam conversion of hydrocarbon gases and vapours to carbon monoxide and hydrogen. Nickel is preferred, despite the susceptibility to sulphur poisoning and consequent need for regeneration, because it affords substantially higher space velocities, with accompanying reductions in plant-investment costs.

(6) *Sulphur-Active Catalysts*. A sulphur-active catalyst is characterized by the requirement that a certain concentration of sulphur in the gas phase is necessary to maintain the catalyst in the sulphide form. The catalyst-evaluation study reported consisted in testing three alternatives in the nickel/nickel-sulphide system. The first investigated was a nickel/nickel-sulphide solid catalyst having a melting point of approximately 1100°F. (593°C.); catalyst activity in this range of temperature was too low for practical use. The second was a solid eutectic mixture of Ni_3S_2: catalyst activity was too low and temperature control too critical for practical use. The third was nickel sulphide impregnated on Porocel, a commercial bauxite carrier, promoted with alumina to retain the molten nickel subsulphide, possibly by means of some sort of wetting action. This catalyst exhibited reasonable activity at temperatures of 1450°-1490°F. (787°-810°C.), the melting range of the nickel subsulphide. Under favourable circumstances the performance of the nickel subsulphide catalyst was considerably lower than that of a sulphur-sensitive catalyst operating at high temperature (1750°-1850°F.: 953°-1008°C.). The attack of the sulphur utilized to stabilize the catalyst resulted in perforation of the alloy tubes after brief periods of operation. Attempts to substitute ceramic-coated tubes were unsuccessful, and to date of the report a satisfactory solution of the reactor-tube corrosion problem had not been found. Possible application of the subsulphide catalyst appears to be limited to specific situations in which large quantities of sulphur are normally associated with the hydrocarbon feed and where the presence of substantial amounts of sulphur can be tolerated in the finished gas.

An appendix to the report contains well illustrated descriptions of test methods used in examination of sulphur-sensitive and sulphur-active catalysts.

Recovery of Nickel from Fat-Hardening Catalysts

M. M. BHASIN, J. GUPTA and J. S. AGGARWAL: 'Recovery of Nickel and Fat from Spent Nickel Catalyst.' *Jnl. Scientific and Industrial Research* (*India*), 1952, vol. 11, June, pp. 248-9.

After a critical discussion of methods which have previously been proposed for recovery of nickel from spent catalyst, the authors give the following details of procedure which they have developed:—

'*Estimation of Nickel and Iron*. A known weight (2-3 g.) of spent catalyst was digested in a Kjeldahl flask with concentrated sulphuric acid containing a few crystals of potassium bisulphate. A small quantity of potassium nitrate was added towards the final stage of digestion, to oxidize the fatty matter and carbon. The residue was diluted with water, filtered, and the filtrate was made up to a known volume. Nickel was estimated in an aliquot with dimethylglyoxime. Iron was estimated colorimetrically.

'*Recovery of Nickel and Fat*. 100 g. of spent catalyst was heated to boiling with 200 cc. of dilute hydrochloric acid (1:1), with constant stirring. Heating was continued for one hour. The mass was cooled and set aside. The supernatant was decanted off and the residue was digested for half an hour with 200 cc. of dilute hydrochloric acid (1:2). The supernatant was decanted off and the residue was again treated with dilute hydrochloric acid (1:3). The process was repeated if the digest gave a positive dimethylglyoxime test. The acid washings were collected and made up to a known volume. Nickel was estimated, in a 25 cc. portion, by dimethylglyoxime.

The residue was washed twice with water, to remove adhering mineral acid, drained, and extracted with

Nickel and Iron in Spent Catalyst: Nickel Recovered

Sample No.	Nickel %	Iron %	Nickel recovered by Acid Digestion %	Fat recovered by Solvent Extraction %
1	6·7	—	6·1	52·0
2	4·4	0·10	4·2	75·0
3	12·2	0·09	11·8	50·5
4	16·6	0·66	16·2	60·0
5	14·2	0·20	13·9	54·0

petroleum ether (b.p. 60°-80°C.), for removing the fat.'

The table shows the amounts of nickel and iron in spent catalysts used in the experiments, and the amounts of nickel recovered by acid digestion.

The recovered nickel can be re-used in the form of precipitated carbonate or formate, for the hydrogenation of oils: the formate is the more efficient. The iron usually present as an impurity in the spent catalyst does not affect the activity of the nickel, but, if preferred, it can be removed from the nickel solution as hydroxide or by means of precipitated chalk.

Surface-Area Measurements on Nickel Catalyst and Powder by Fatty-Acid Adsorption Method

C. ORR, H. G. BLOCKER and S. L. CRAIG: 'Surface Areas of Metals and Metal Compounds: A Rapid Method of Determination.' *Jnl. of Metals*, 1952, vol. 4, June, *Trans. Amer. Inst. Mining and Metallurgical Engineers*, pp. 657-60: T.P. 3298E.

Gas-adsorption methods for measuring the surface area of finely divided materials have been used to a considerable extent in research on the corrosion of metals and their catalytic activity. The apparatus required for this method of measurement is, however, somewhat elaborate, and the length of time required for a determination has militated against the general use of the procedure. The authors of the present paper propose a simplified technique, utilizing fatty acids.

In the procedure recommended a sample of the material of which the surface-area measurement is required is exposed to a fatty-acid solution of known concentration. By analysis of an aliquot of the solution, the concentration after adsorption has occurred may be determined. The difference between the initial quantity of acid in solution and the final quantity is the amount of acid adsorbed by the sample. The specific surface area of the adsorbent material may be calculated from the quantity of acid adsorbed, and the weight of the sample. Typical surface-area measurements made by this method are compared, in the paper, with measurements made on the same materials by other procedures already accepted as standard. The materials for which measurements are recorded include a nickel catalyst, and nickel powder.

Chemical Analysis of Nickel for Electronic Applications: A.S.T.M. Methods

AMER. SOC. TESTING MATERIALS: 'Proposed Methods for Chemical Analysis of Electronic Nickel.' Appendix II to Report of Committee B-4 on Electrical Heating, Resistance and Related Alloys. *A.S.T.M. Preprint* 10, June, 1952, pp. 8-12.

The methods recommended cover procedures for chemical analysis of nickel having composition within the following limits: cobalt 0·01-1·0, copper 0·01-1·0, iron 0·01-1·0, titanium 0·001-0·1, manganese 0·01-1·5, per cent. The analytical procedures described are:—

Cobalt by the Nitroso-R-Salt (Photometric) Method
Copper by the Hydrobromic (Photometric) Method
Manganese by the Periodate (Photometric) Method
Iron and Titanium by the Tiron (Photometric) Method

Test for Determination of Relative Thermionic Emissive Properties of Metals

AMER. SOC. TESTING MATERIALS: 'Proposed Tentative Method of Test for Relative Thermionic Emissive Properties of Materials used in Electron Tubes.' Contained in Report of Committee B-4 on Electrical Heating, Resistance and Related Alloys. *A.S.T.M. Preprint* 10, June, 1952, pp. 13-29.

Covering tests for determination of the relative merits of various radio tube materials (cathode nickel alloys, cathode coating material, and heater insulation coating materials), based on their effect on the electrical characteristics of a typical high-vacuum tube (standard diode). Full details are given of design and materials of the standard diode. In all tests the material or process to be tested is substituted for the standard material or process described in the specification, and the latter constitutes the standard for comparison. Material for the control cathode in the standard diode is International Nickel Company's No. 220 alloy (Grade 11 of A.S.T.M. Specification B-239), of which a selected sample, known as melt No. 66, is used. Chemical requirements for this material, and the composition of the selected melt, are shown in the table below.

Chemical Requirements for Cathode Material

(Maxima except where range is shown)

	Ni+Co %	C %	Cu %	Fe %	Mn %	S %	Si %	Mg %
No. 220 ..	99·0	0·15	0·20	0·20	0·20	0·008	0·01-0·05	0·01-0·10
Melt 66 (*a*, *b*)	99·7	0·06	0·02	0·07	0·10	0·004	0·03 max.	0·038

(*a*) Believed to be the most reliable percentage composition, from the reports of various laboratories who have co-operated in analysis.

(*b*) Additional items of analysis for melt 66 are: aluminium 0·003, boron 0·003, cobalt 0·75, chromium 0·0008, phosphorus 0·002, titanium 0·03, per cent.

Quadrivalent Nickel

R. S. NYHOLM: 'Studies in Co-ordination Chemistry. Part IX. Quadrivalent Nickel.' *Jnl. Chemical Soc.*, 1951, Oct., pp. 2602-7.

Report of study of the action of several oxidizing agents on the compound $[NiCl_2 (diarsine)_2] Cl$ where 'diarsine' represents *o*-phenylenebisdimethylarsine. The properties of the compounds are discussed, and the literature dealing with ter- and quadri-valent nickel is reviewed.

X-Ray Fluorescent Analysis of Nickel and Nickel Alloys

P. K. KOH and B. CAUGHERTY: 'Metallurgical Applications of X-Ray Fluorescent Analysis.' *Jnl. Applied Physics*, 1952, vol. 23, Apr., pp. 427-33.

Techniques are described for making fluorescent analysis, using an X-ray Geiger counter goniometer: consideration is given to the influence of potential variations, preparation of specimen, and thickness of the diffracting crystal. The observed intensities of fluorescent radiation from seventeen commercially pure elements (including nickel) were compared, under a constant primary radiation which could be closely controlled.

Intensities of fluorescent spectra were measured on constituents of iron-nickel, iron-chromium and iron-nickel-chromium alloys: calibration curves correlating line intensity with percentage weight composition are given for binary iron-nickel and iron-chromium alloys.

The thickness beyond which fluorescent intensity becomes constant was determined for pure iron, nickel, and chromium, and up to that thickness an empirical plot of fluorescent intensity vs. thickness of layer was established for each element. These curves can be applied to measurement of the thickness of very thin electrodeposited and other coatings.

Examples are also given indicating the applications of the fluorescent analytical technique to the study of oxidation and diffusion processes in metallic systems: typical illustrations relate to the chromium-iron, and nickel-iron alloys, and nickel-chromium stainless steel. The authors also describe technique for fluorescent analysis of powders derived from chemical or electrolytic extraction of certain phases of the alloys studied. This method supplements the diffraction data in cases in which a wide solid solubility exists.

Determination of Large Amounts of Nickel by the Dimethylglyoxime Procedure

E. L. BICKERDIKE and H. H. WILLARD: 'Dimethylglyoxime for Determination of Nickel in Large Amounts.' *Analytical Chemistry*, 1952, vol. 24, June, p. 1026.

Gravimetric determination of nickel as nickel dimethylglyoxime is generally limited to samples containing not more than 30 mg. of nickel, due to the bulkiness of the precipitate formed. The authors of this paper describe modifications of procedure by which it is possible to handle, with satisfactory accuracy, precipitates containing up to 100 mg. of nickel.

The method employs the principle of precipitation from a homogeneous solution, originally developed by Willard, which gives a coarsely crystalline, compact and dark-coloured precipitate, which does not adhere to glass.

Details of the analytical procedure are given below: 'Dilute the solution to 200 ml. and adjust the pH to 2-3 with hydrochloric acid. Add 20 grams of urea. Add 50 ml. of a hot (50°C.) solution of dimethylglyoxime in 1-propanol (1 gram of reagent per 100 ml. of solvent), and heat on a water bath for an hour. Cover the beaker or Erlenmeyer flask with a watch glass to prevent excessive loss of solvent. At the end of this time the solution should be alkaline to litmus. Add a few drops of the dimethylglyoxime solution, to test for completeness of precipitation. Cool to room temperature and filter into a coarse filtering crucible (Selas No. 2010). Wash with cold water and dry to constant weight at 110°-120°C. The nickel dimethylglyoxime contains 20·32 per cent. nickel.'

It is stated that this procedure has been tested on samples containing cobalt-free nickel sulphate. Five samples, in which electrolytic determination had given a value of 0·0996 gram, yielded the following results: 0·0996, 0·0997, 0·0995, 0·0996 and 0·0996 gram; average 0·0996 gram.

Volumetric Determination of Nickel in Steel: Use of Versenate in Titration

See abstract on p. 213.

Nickel in Hydrogen Diffuser Element

J. L. SNOEK and E. J. HAES: 'Laboratory Apparatus for the Production of a Steady Flow of Very Pure Hydrogen.' *Applied Scientific Research*, 1950, vol.A.2, No. 4, pp. 326-8.

The authors describe (with illustration) apparatus which embodies a diffuser element consisting of twelve thin-walled nickel tubes in parallel. On being heated to 950°C. and exposed to an excess pressure of about one atmosphere, this diffuser permits a steady flow of about a quarter of a litre per minute of the purest hydrogen, at atmospheric pressure. Nickel has been found particularly suitable for this purpose, and the apparatus described, which is simple in design, has proved to be strong, giving a life of several hundreds of hours. Output is uniform, and the hydrogen coming from the diffuser shows a high degree of purity.

Physiological Studies of Effects of Nickel on Rats

S. S. PHATAK and V. N. PATWARDHAN: 'Toxicity of Nickel: Accumulation of Nickel in Rats Fed on Nickel-containing Diets and its Elimination.' *Jnl. Scientific and Industrial Research (India)*, 1952, vol. 11, May, pp. 173-6.

Earlier investigations on the effects of feeding nickel-containing diets to rats and monkeys had shown that no toxic effects could be demonstrated even after continuance of such diets for 4-6 months, at levels of 25-100 mg. nickel per 100 g. of diet (*ibid.*, 1950, vol. 9, May, pp. 70-6; *Nickel Bulletin*, 1950, vol. 23, No. 6, p. 102). In these experiments it was also observed that after 9-weeks' feeding small quantities of nickel were retained in the bodies of the animals.

This later study was made to determine whether, on continued feeding, the amount of accumulated nickel in the various tissues would continue to increase, and how soon after discontinuance of feeding of a nickel-containing diet the body would be clear of nickel. Full particulars are given of the composition of the diet, which was mixed with nickel catalyst to give the required concentration of nickel.

The results (details of which are tabulated) show that the general condition and growth of rats fed on the nickel-containing diets for 16 months were comparable with those of rats on nickel-free diets. Maximum accumulation of nickel in bones and soft tissues was observed after 8 months' continuous feeding: on a low-protein diet the accumulation was less in all tissues (with the exception of the intestines) than when the protein content was on a normal level. On removal of nickel from the diet the accumulated nickel was eliminated by excretion through urine and faeces, elimination being complete after 40 days.

ELECTRODEPOSITION AND OTHER COATING METHODS

Polarization and Overvoltage: Bibliography

R. A. SCHAEFER and W. KING: 'Polarization and Overvoltage: Selected Bibliographical Abstracts.' *Plating*, 1952, vol. 39, May, pp. 487-94; June, pp. 627-34.

The abstracts presented have been compiled from 'Bibliography on Polarization and Overvoltage' originally prepared for the Research Committee of the American Electroplaters' Society by D. D. BEROLZHEIMER and K. M. BROWN in 1948, and amplified, by the present writers, to include references to the end of 1949. The total *bibliography* thus prepared comprised over 2000 references: the items presented in *Plating* have been selected to include reports of important researches relating to polarization and overvoltage as affecting electrodeposition and allied processes.

Heavy Nickel Plating of Paper Drum Driers

'Nickel Plating Large Drum Driers.' *Electroplating*, 1952, vol. 5, July, p. 229.

This short article is an illustrated note on nickel-plating of paper-drier cylinders, as carried out by the Swedish firm of Kvarnströms Fabriks, A.B., Stockholm. In 1944 trouble had been experienced with cast iron driers in a plant where the water supply was specially corrosive, and the electrodeposited nickel coating then applied as a remedial measure proved highly successful, giving not only protection from corrosion, but also an improved glaze on the paper treated. Due to shortage of nickel at that time, only a relatively thin coating was deposited, but the practice is now to provide a coating of 1-3 mm. (0·04-0·12 in.) or more for this application, and for some types of rolls and cylinders a thickness of ¼-in. of nickel has been used. Due to the size of the parts to be treated, the coating is deposited *in situ*. The success which has attended this use of heavy electrodeposited nickel suggests the potential value of such treatment for other heavy industrial applications in which smoothness of surface and good resistance to corrosion are requisite.

Nickel Plating of Aluminium Alloy Propeller Blades

'Seagoing Propeller Blades Resist Water Erosion.' *Nickel Topics*, 1952, vol. 5, No. 4, p. 2.

Description of the rubber-nickel coating which is being used to protect propeller blades on seaplanes and flying boats. It is stated that the composite coating provides highly satisfactory resistance to erosion and corrosion, without damage to the fatigue strength of the blades. Adhesion is uniform over the blade, and shear tests indicate that the nickel-rubber and rubber-aluminium bonds are very strong, and that the strength of the composite is limited only by the properties which can be developed in the rubber itself. Coated blades which have been in service for some time on amphibian craft and patrol bombers are still giving satisfactory service after hundreds of take-offs. (See earlier reference to this process in *Nickel Bulletin*, 1952, vol. 25, No. 4, p. 97.)

Electrodeposition of Tungsten-Nickel and Other Tungsten Alloys

W. E. CLARK and M. H. LIETZKE: 'The Mechanism of the Tungsten Alloy Plating Process.' *Jnl. Electrochemical Soc.*, 1952, vol. 99, June, pp. 245-9.

The electrodeposition of alloys of tungsten with iron, cobalt, or nickel has been the subject of a number of papers during recent years, but most of the published information has dealt with development of plating baths rather than with the mechanism of the tungstate reduction. The present paper briefly reviews some of the previous theoretical work on tungsten-alloy deposition and presents additional data designed to elucidate the reduction process. The new work deals almost entirely with cobalt-tungsten alloy deposition, and, in addition, energies of activation have been calculated for deposition of iron-tungsten alloys. Due to the similar behaviour of iron, cobalt and nickel in tungsten-alloy plating baths, it is considered reasonable to suppose that conclusions drawn from the cobalt-tungsten bath will be broadly applicable to nickel-tungsten and iron-tungsten solutions. The mechanism postulated for the deposition of tungsten alloys includes (1) the deposition of a film of partly reduced tungstate on the cathode, and (2) the catalytic reduction of this film by hydrogen, in presence of freshly deposited iron, cobalt, or nickel.

Plating of Powder-Metal Compacts

'Plating Powder-Metal Compacts.' *Electroplating*, 1952, vol. 5, June, p. 201.

The article contains a brief discussion of methods which have been proposed to overcome difficulties encountered in plating of powder-metal parts, and gives details of the claims made in *British Patent* 659,073 (EKSTRAND and THOLAND, INC.: see abstract in *Nickel Bulletin*, 1951, vol. 24, No. 10, p. 219). Typical plating schedules are quoted and

properties of parts plated by the method described are considered, including their corrosion-resisting characteristics.

Electroforming of Metal Gunsight Graticules

D. C. GRESHAM: 'The Manufacture of Metal Diaphragms having Very Accurate Perforations.' *Process Engravers' Monthly*, 1951, vol. 58, Feb., pp. 42, 45.

Metal gunsight graticules, of which large numbers were made during the war, consist of metal discs through which are etched very accurate narrow slots having very sharp corners. This article describes a process which was developed for making these discs, and which has since then been applied to production of other precision parts, such as masks for sound-recording machines and sensitometers.

Sheets of thin, highly polished copper (about 0·012 in. thick) are coated on both sides with a layer of Bakelite resin (by the method described *ibid.*, Dec., 1950, p. 358). Both sides are then coated with a layer of bichromated gum, and the metal sheet is placed between two negatives of the design to be etched, in such a way that the images on the negatives fall into register. An exposure is then made to a high-intensity light source, from both sides simultaneously, after which the plate is washed in cold water, to remove the still-soluble gum layer, leaving an image in hardened gum on top of the resin. The gum is then dried, after which the unprotected areas of resin are dissolved away in lactic acid containing a small proportion of ethyl lactate. When this 'development' of the resin image is complete the gum layer is removed, leaving a resin resist on both sides of the metal in register, wherever the holes are finally to appear.

After suitable chemical cleaning, the plate is put into a nickel-plating bath, and a layer of nickel some 0·0005-in. thick is deposited on the copper wherever it is unprotected by the insulating resin resist. After nickel plating the resist is removed, preferably by immersing the plate in a boiling caustic bath. This leaves a copper sheet bearing, on both sides, a stencil of nickel, the openings in which are in register. The edges of the nickel stencil will be very sharp, and the corners will have very accurate configuration. The plate is next put into an ordinary copper-plating bath and connected as anode. In this bath the copper is etched right through from both sides, and during this operation the etching undercuts the nickel to a certain extent. Thus, at the end of the electrolytic etching operation the boundaries of the metal are formed by a knife edge of nickel slightly overhanging the copper, which forms the main body of the diaphragm. The process is the subject of British Patent 568,003.

The Salt-Spray Test

F. L. LAQUE: 'A Critical Look at Salt Spray Tests.'* Reprint from *Materials and Methods*, Feb. and Mar., 1952. Issued by International Nickel Co., Inc., July, 1952; 13 pp.

For abstract see *Nickel Bulletin*, 1952, vol. 25, Nos. 5 and 6, pp. 129 and 149.

* *We shall be pleased to supply a free copy of this publication.*

NON-FERROUS ALLOYS

Inter-Relationship between Structure and Modulus of Elasticity in Binary Nickel Alloys

W. KÖSTER and W. RAUSCHER: 'Relations between the Modulus of Elasticity of Binary Alloys and their Structure.' *Nat. Advisory Committee for Aeronautics, Tech. Memorandum* 1321, Nov., 1951; 49 pp. Translation from *Zeitsch. für Metallkunde*, 1948, vol. 39, pp. 111-20.

Summary of the literature, supplemented by report of the authors' own investigations on the elastic modulus of binary alloys as a function of composition. Systems of major significance are discussed, with a view to obtaining fundamental indications regarding the relation between lattice structure, nature of alloying, and elastic behaviour. Nickel alloys for which data are included are the following series: copper-nickel, nickel-manganese, nickel-beryllium, magnesium-nickel.

Hardness Conversion Table for Nickel and High-Nickel Alloys

AMER. SOC. TESTING MATERIALS: 'Standard Hardness Conversion Table for Nickel and High-Nickel Alloys. Relationship between Diamond Pyramid Hardness, Brinell Hardness and Rockwell Hardness.' Contained in Report of Committee E-1 on Methods of Testing; *A.S.T.M. Preprint* 50, June, 1952, pp. 13-15.

The tables cover materials containing over 50 per cent. of nickel: the values given are intended to apply particularly to nickel, nickel-copper, nickel-copper-aluminium, nickel-chromium-iron and nickel-aluminium-silicon specimens finished to commercial mill standards for hardness testing, covering the entire range of these alloys from the annealed to the heavily cold-worked or age-hardened conditions, or both, including intermediate conditions. The conversions are based on a report by F. P. HUSTON (*Proc. Amer. Soc. Testing Materials*, 1947, vol. 47, pp. 770-81).

The standard was adopted by the Society at the Annual Meeting, June, 1952.

Diamond Pyramid Hardness Testing: Tentative Standard

See abstract on p. 194.

Copper-Nickel and Copper-Nickel-Zinc Alloys: Reference Data

COPPER DEVELOPMENT ASSOCN.: 'Classification of Copper and Copper Alloys.' *C.D.A. Publn.* 36; 5th edn., 1952; 227 pp.

The information given in this publication was first collected during the early part of the war, to meet the needs of engineer-users and designers for concise tabulated data on the more common copper-base materials. Revision of the original publication has afforded an opportunity for inclusion of information relating to some additional alloys which are now of commercial importance, and of some specifications which have recently been issued.

The information given in the tables includes data on

grades of raw copper and properties of wrought copper products; cast and wrought copper alloys of special types, including those for conductivity applications; brass plate, sheet, strip, tube, rods and sections, castings, wire; aluminium bronze, gunmetals and tin bronzes; copper-lead alloys for bearings; copper-manganese alloys; wrough copper-nickel and copper-nickel-zinc alloys ('nickel silvers'); silicon bronze; materials for welding, brazing and soldering.

Typical compositions are given, together with representative values for tensile strength and related properties, and diamond-pyramid hardness values. British Standard and other British specifications for the respective materials are shown.

Annealing and Pickling of Nickel and Nickel Alloys

CENTRE D'INFORMATION DU NICKEL, PARIS: 'Annealing and Pickling of Nickel, Monel, Inconel and Nickel Silver Alloys.' *Publn. AA-5*, 1952; 15 pp.

This brochure gives details of equipment and procedure recommended for treatment of the materials named.

Cold Working of Non-Ferrous Alloys: Institute of Metals Symposium

INST. METALS: 'The Cold Working of Non-Ferrous Metals and Alloys.' *Monograph and Report Series* No. 12, Published by the Institute, May, 1952; 207 pp. Price 15/–.

Contains the papers presented at the symposium held in March, 1951, with discussions arising from them. For abstracts of papers see *Nickel Bulletin*, 1951, vol. 24, No. 4, pp. 77-8.

Extrusion of Nickel Alloys and Other Materials: Recent Developments

See abstracts on pp. 218 and 219.

Emissivities of Liquid Iron-Copper-Nickel Alloys

D. B. SMITH and J. CHIPMAN: 'Optical Temperature Scale and Emissivities of Liquid Iron-Copper-Nickel Alloys.' *Jnl. of Metals*, 1952, vol. 4, June; *Trans. Amer. Inst. Mining and Metallurgical Engineers*, pp. 643-4; T.P. 3290D.

The work reported was carried out as a preliminary to the study of sulphur activities in the liquid system iron-copper-nickel: it is a continuation of research by SHERMAN and others (*Trans. Amer. Inst. Mining and Metallurgical Engineers*, 1950, vol. 188, p. 334; *Jnl. of Metals*, Feb., 1950). The equipment and experimental technique described in the 1950 paper were also employed in the later work.

Curves show: (1) optical vs. true temperatures for typical compositions in the iron-nickel, copper-nickel, and copper-iron series, and for pure copper; (2) emissivities of iron-copper, nickel-copper, iron-nickel and iron-nickel-copper alloys, all at 1535°C.

It is noted that in each of the binary systems containing copper maximum emissivity was found at about 20-30 per cent. copper. Maximum deviation from the simple law of mixtures was observed at about 50-60 per cent. copper. It is noted that LOWERY, BOR and WILKINSON found a maximum absorption coefficient in copper-nickel solid solutions at about the same percentage of copper as the maximum in emissivity observed in this investigation.

Magnetostriction in High-Nickel Alloys

E. W. LEE: 'Magnetostriction of Some Ferromagnetic Alloys.' *Jnl. Iron and Steel Inst.*, 1952, vol. 171, June, pp. 160-4.

The paper opens with an illustrated description of the apparatus used, which comprises a double roller and mirror system, capable of giving accurate measurements of magnetostriction of ferromagnetic materials. Data are then presented on magnetostriction effects observed, in various fields, in the following materials: iron, cobalt, nickel-iron alloys (36, 42 and 48 per cent. nickel), W 5 and W 6 alloys (nickel-silicon alloys), Monel, Mangonic (nickel-manganese alloy), and a series of nickel-cobalt alloys (nickel ranging from 90·2 to 10·53 per cent.). Temperature coefficients of magnetostriction, over the range 5°-30°C., were measured on Mangonic, W 6, and the 36 and 42 per cent. nickel nickel-iron alloys

Constitution of Nickel-Rich Nickel-Chromium-Titanium Alloys

A. TAYLOR and R. W. FLOYD: 'The Constitution of Nickel-Rich Alloys of the Nickel-Chromium-Titanium System.' *Jnl. Inst. Metals*, 1951-52, vol. 80, pp. 577-87; *Monthly Jnl.*, July, 1952.

The work reported was designed to establish the effects of additions of titanium to nickel-chromium alloys; it consisted in micrographic analysis of the structure of nickel-rich alloys containing up to about 30 per cent. of titanium. Investigation of the ternary system was preceded by examination of the binary nickel-chromium and nickel-titanium systems.

The paper comprises four sections, covering, respectively, the experimental procedure adopted, and the nickel-chromium, the nickel-titanium, and the nickel-chromium-titanium systems.

New equilibrium diagrams are presented for the two binary systems, and for the nickel-rich ternary alloys partial equilibrium diagrams corresponding to the 750°, 1000° and 1150°C. isothermals have been constructed. Isoparametric contours have been drawn for the nickel-rich primary solid solution, or γ phase, and it is shown that the hexagonal phase, Ni_3Ti, grows epitaxially on the octahedral planes of γ, on account of the close similarity in their interatomic distances. The boundary separating magnetic from non-magnetic ternary γ-phase alloys at 20°C. is indicated in the diagram.

Nickel-containing Electrical-Resistance Materials

HENRY WIGGIN AND CO., LTD.: 'Wiggin Electrical Resistance Materials.'* *Publn.* 510, 1952; 102 pp.

This publication, which is a revised and amplified edition of one issued in 1948, contains full details of the properties and uses of alloys of the nickel-chromium-base Brightray series, Ferry (nickel-copper), and nickel, as relating to their electrical-resistance applications.

* *We shall be pleased to supply a free copy of this publication.*

Flow Lines in Cold-Worked Nickel Silver

R. ERGANG: 'The Origin and Prevention of Flow Lines Occurring during Drawing of Brass and Nickel Silver Hollowware.' Paper presented at the 4th. International Mechanical Engineering Congress, Stockholm, June, 1952; 13 pp.

Cf. paper abstracted in *Nickel Bulletin*, 1952, vol. 25, No. 6, pp. 150-1.

Effect of Prior Strain at Low Temperatures on Room-Temperature Properties of Nickel and Nickel Silver

See abstract on p. 195.

The Ni_3Al Phase in Nickel-Aluminium Alloys

R. W. FLOYD: 'The Formation of the Ni_3Al Phase in Nickel-Aluminium Alloys.' *Jnl. Inst. Metals*, 1951-52, vol. 80; *Monthly Jnl.*, June, 1952, pp. 551-3.

The author opens with a discussion of published literature bearing on the Ni_3Al phase, calling particular attention to variations between the conclusions drawn by ALEXANDER and VAUGHAN (*ibid.*, 1937, vol. 61, p. 247) and by SCHRAMM (*Zeitsch. für Metallkunde*, 1941, vol. 33, p. 347). The experimental work recorded in the present paper was undertaken to determine qualitatively the nature of the reaction by which the Ni_3Al phase is formed, without attempting to establish the temperature of its formation or the precise position of any phase boundaries.

Previous work had shown that formation of this phase takes place too rapidly in the binary nickel-aluminium alloys for its progress to be observable directly by micro-examination of quenched alloys. Also, the eutectic is difficult to detect, on account of the broadening of the γ-phase field immediately below the solidus. In contrast to the rapid rate of reaction in nickel-aluminium alloys, the response to heat-treatment of nickel-chromium alloys is known to be sluggish, and it was believed that replacement, in nickel-aluminium alloys, of a small part of the nickel by chromium would slow down the rate of reaction taking place during solidification. (Evidence obtained by the author from other work had shown that the addition of chromium in small amounts did not introduce any new phase.) Microscopical examination was therefore made of a series of binary nickel-aluminium alloys containing 20-30 at. per cent. of aluminium, and of a corresponding series of nickel-chromium-aluminium alloys containing 2½ at. per cent. chromium, at the same aluminium levels. A series of ten photomicrographs illustrates typical results, which are discussed in detail. It is concluded that the Ni_3Al phase is the product of a peritectic reaction between the melt and the β(NiAl) phase.

It is suggested that the method adopted in this investigation, of studying the binary viâ a related ternary system, although unusual, is inherently sound, and that it could possibly be used with success in other cases in which a reaction is either too rapid or too slow for observation by direct methods. It is, however, emphasized that results obtained on a complex system can satisfactorily be applied to a less complex one only if there is sufficient knowledge of the effects of the addition element used to form the ternary alloy. Unless this is the case, serious difficulties in interpretation may arise, as has been shown in studies of systems in which the presence of impurities has been unavoidable.

Thermal Expansion Characteristics of Nickel-containing Aluminium-base Alloys

P. HIDNERT and H. S. KRIDER: 'Thermal Expansion of Aluminum and Some Aluminum Alloys.' *Jnl. Research, Nat. Bur. Standards*, 1952, vol. 48, Mar., pp. 209-20; R.P. 2308.

Data on linear thermal expansion of aluminium and a wide range of aluminium-base alloys, for various temperature ranges between $-50°$ and $+$ 400°C., with evaluation of the influence of some of the individual elements on this property. Ternary diagrams show the effect of composition on the coefficients of expansion of aluminium-copper-nickel and aluminium-silicon-copper alloys. The effects of additions of two or three elements (copper, nickel, manganese and molybdenum), on coefficients of expansion of aluminium-silicon alloys, are indicated.

Transformations in Cobalt-Nickel Alloys

J. B. HESS and C. S. BARRETT: 'Transformation in Cobalt-Nickel Alloys.' *Jnl. of Metals*, 1952, vol. 4, June; *Trans. Amer. Inst. Mining and Metallurgical Engineers*, pp. 645-7; T.P. 3269 E.

Attainment of equilibrium between different phases in cobalt-rich alloys requires extremely long annealing periods when temperatures below about 700°C. are used. The authors point out that the fact that a transformation from face-centred cubic to close-packed hexagonal readily takes place at temperatures below this in the cobalt-rich solid solutions is not an indication that thermally activated processes occur at an appreciable rate, since the transformation is well established as being martensitic in character. It has been found that wide divergence between heating and cooling experiments, and high sensitivity to prior heat-treatment make it difficult to judge temperatures of equilibrium between the phases.

One object of the work reported in the present paper was to determine whether information on the relative stability of the various phases could be gained by substituting plastic deformation for thermal agitation. Procedures were developed which led to the determination of a diffusionless type of phase diagram, which represents the temperature of equal stability for phases of the same composition, and the technique was applied to the investigation of cobalt-nickel alloys. A further aim of the research was to ascertain whether deformation would generate frequent stacking faults which would in themselves produce thin lamellae of a phase having higher free energy than the parent phase. Alloys containing up to about 35 per cent. of nickel were studied.

A curve shows the temperatures at which deformation begins to transform the cubic to the hexagonal phase, and a similar curve indicates the strain-induced reverse transformation in the same alloys. The two

curves were found to agree within the limits of experimental error: they thus determine a curve of equal stability, which is also judged to be the curve giving equal free energy for the phases when they have the same composition. Stacking faults were detected after deformation at temperatures below, but not definitely above, this curve.

Production of Nickel-containing 'Heavy Alloy'

'Heavy Alloy.' *Flight*, 1952, vol. 62, July 4, p. 9.

Short note giving details of method of production of this 90 per cent. tungsten alloy, which is much used for aileron balance and similar components in which a heavy mass is required in small space. The alloy is made by mixing powdered tungsten with nickel, copper, and a wax binder, and compressing the mass at 5-10 tons per sq. in. The compacted material is heated in a hydrogen atmosphere to 1000°C., which removes the wax and hardens the compound, and is subsequently sintered for 15 minutes, during which treatment it solidifies, increasing in density by shrinkage of about 20 per cent.

Tungsten-Chromium-Nickel Alloys

H. BÜCKLE: 'Study of High Tungsten-Chromium Alloys containing Nickel.' *Recherche Aéronautique*, 1951, No. 24, Nov.-Dec., pp. 49-55.

Report of investigation of the ternary system, by means of photomicrographic study and micro-hardness tests. Two clearly marked phases were observed: a ternary solid solution and a phase which is of high nickel content. This latter phase is susceptible to considerable ageing effects. A new conception of the binary tungsten-nickel diagram is proposed, which differs appreciably from that put forward by ELLINGER and SYKES (*Trans. Amer. Soc. Metals*, 1940, vol. 28, p. 619; *Nickel Bulletin*, 1939, vol. 12, No. 11, p. 217).

Structure of Nickel-Magnesium Alloys

K. SCHUBERT and K. ANDERKO: 'Crystal Structure of $NiMg_2$ and $AuMg_3$.' *Naturwissenschaften*, 1951, vol. 38, p. 259: *Chemical Abstracts*, 1952, vol. 46, Apr. 10, p. 2870.

'$NiMg_2$ has D_6^4–$C6_2^2$ structure and is homotectic with $CuAl_2$.'

Lattice Spacings and Densities of Nickel-Gold Alloys

E. C. ELLWOOD and K. G. BAGLEY: 'The Lattice Spacings and Densities of Gold-Nickel Alloys at 25°C.' *Jnl. Inst. Metals*, 1951-52, vol. 80, pp. 617-19; *Monthly Jnl.*, July, 1952.

It was shown by Ellwood that certain anomalies in the lattice spacing and density of the aluminium-zinc solid solutions in the range of the (α-α') immiscibility loop are probably associated with Brillouin-zone effects (*ibid.*, 1951-52, vol. 80, p. 217). The work reported in the present paper was carried out to determine whether another system containing a similar loop showed like effects. The gold-nickel system was chosen because the maximum temperature of miscibility appeared to be lower than that found in other systems. The alloys examined contained 10, 20, 25, 30, 40, 50, 60, 65, 70, 75, 80, 85, 90 and 95 at. per cent. nickel, and the pure metals were also studied.

The conclusions drawn are given below:—

'Brillouin-zone overlaps take place in the solid solutions of gold and nickel, and are accompanied by the formation of vacant lattice sites. This phenomenon is therefore not confined to the solid solutions of zinc in aluminium.

'Nickel contributes about 3·2 electrons per atom when dissolved in gold up to 60 at. per cent.

'Brillouin-zone overlap occurs when gold is added to nickel, that is on a decreasing electron concentration, suggesting that the $N(E)$ curve of nickel is complex and that it suffers modification on alloying.'

Welding of Nickel and Nickel Alloys Used in the Dairy Industry

E. T. GILL and E. N. SIMONS: 'Welding Nickel and Nickel Alloys, etc.' *Dairy Industries*, 1952, vol. 17, May, pp. 433-6.

Details of recommended procedure for welding nickel, Monel and Inconel, by the various methods applicable for joining the respective materials. The welding of magnesium and its alloys is also considered.

NICKEL-IRON ALLOYS

Influence of Nickel on Diffusion and Precipitation of Carbon in Iron

C. WERT: Diffusion and Precipitation of Carbon in Some Alloys of Iron.' *Jnl. of Metals*, 1952, vol. 4, June; *Trans. Amer. Inst. Mining and Metallurgical Engineers*, pp. 602-3: T.N. 111E.

Report of work on pure iron and on binary alloys containing, respectively, nickel 0·5, molybdenum 0·9, chromium 0·5, manganese 0·5, or vanadium 0·5, per cent. The investigation confirmed the findings of earlier workers that for pure iron internal friction is a reliable indicator of carbon content. It was found that the presence of the alloy elements named, in the amounts studied, does not affect the relaxation peak of carbon in α-iron. It is presumed that, in such amounts, they do not sensibly alter the rate of diffusion of carbon in iron. With the exception of vanadium, these alloying elements do not affect rate of precipitation of carbon in α-iron. Vanadium hastens precipitation of carbon, an effect which is tentatively interpreted as indicating that it provides more precipitation nuclei for the carbide. These latter conclusions are qualified by the statement that in some of the alloys examined some carbon is combined in an unknown way. The presence of this carbon appears in no way to affect the behaviour of the 'free' carbon, except in the vanadium alloy.

Magnetic Properties of Nickel and Nickel Alloys

K. HOSELITZ: 'Ferromagnetic Properties of Metals and Alloys.' *Published by Oxford University Press*, 1952; 317 pp.

This book is one of a series of monographs on the physics and chemistry of materials. The respective

volumes are intended to summarize recent results in academic or long-range research, in a form which will be useful to physicists in universities and in Government and industrial laboratories.

The author, who has been for the past twelve years engaged in the study of ferromagnetic metals and alloys, records that he has continuously felt the need for a comprehensive but concise account of the recent theories and experimental results connected with this subject, and that in writing this book he has confined himself to results which he has required in his own work on magnetic alloys and magnetic measurements.

Following a short introduction and synopsis of the contents of the book, the detailed information is presented in sections dealing, respectively, with the magnetization curve; the physical properties and structure of metals and alloys as related to their magnetic characteristics; magnetic analysis (an aspect of the subject on which this is believed to be the first comprehensive treatise); magnetically soft materials (including extensive reference to straight and complex nickel-iron alloys); hard magnetic materials (permanent-magnet steels and alloys, including the nickel-aluminium-iron-base types). With regard to the chapter on the properties of metals and alloys, the author emphasizes that the book is not intended to be a treatise on metallurgy, and that the material included in this section has been strictly limited to aspects of the subject which have presented problems in his own work. This limitation is, however, partially offset by inclusion of a comprehensive bibliography giving reference to a wider field of reading, and *bibliographies* are a feature also of all other chapters of the book.

Appendices cover:—

A. Calculation of limiting size for isolated single domains of cube shape in iron.

B. Demagnetizing factors.

C. Saturation intensity and Curie temperature of some ferromagnetic metals and alloys: tabulated data, with references to the sources of the information given.

Structure and Magnetic Properties of Alnico 5 Permanent-Magnet Alloy

R. D. HEIDENREICH and E. A. NESBITT: 'Physical Structure and Magnetic Anisotropy of Alnico 5. *Jnl. Applied Physics*, 1952, vol. 23, Mar., pp. 352-65; 366-71.

The authors report examination of the alloy by 'electron metallography', this term being used to denote the combined electron-microscope and electron-diffraction results of a structural investigation. The combined method offers a high-resolution technique for studying structures of a size below that at which X-ray diffraction and light microscopy are effective. It is particularly suitable for examination of alloys exhibiting only a very small amount of a precipitated phase, or materials in which that phase is highly dispersed, having a small crystal and a small particle size. The composition of the alloy examined is given as nickel 14, aluminium 8, cobalt 24, copper 3, iron 51, per cent.

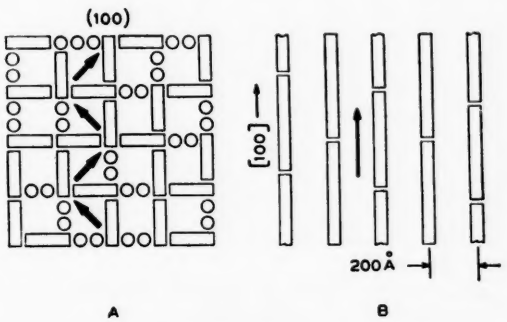
The results indicate that the high coercive force and anisotropy of Alnico 5 are caused by a very finely divided precipitate produced by the heat-treatment applied to permanent magnets. This precipitate is a transition structure rich in cobalt, and is face-centred cubic, with $a_o = 10$ Å. It appears as rods growing along the [100] directions of the matrix crystal when no magnetic field is applied during heat-treatment. The size of the precipitate rods associated with optimum properties is approximately 75-100Å × 400Å long: the spacing between the rows of rods is about 200Å. The rods are not distinctly resolved in the electron images unless they are grown by ageing at 800°C. Their orientation and structure are clearly evident in the electron-diffraction patterns at all stages of growth. The precipitate responds to a magnetic field applied during heat-treatment, both by suppression of nuclei making an angle greater than about 70° with the field, and by forcing the rods off the [100] direction into that of the field. The precipitate rods tend to scatter in direction about the field vector when the field is off the [100] plane, but are aligned accurately when the field is along it.

See also next abstract

E. A. NESBITT and R. D. HEIDENREICH: 'The Magnetic Structure of Alnico 5.' *Electrical Engineering*, 1952, vol. 71, June, pp. 530-4.

The paper is concerned with a study of (1) the mechanism which permits response to heat-treatment in a magnetic field, which is capable of increasing threefold the figure of merit (BH) of Alnico 5, and (2) the reason for the high coercive force of this alloy, which is of the order of 600 oersteds.

The experimental work described was guided by the theory advanced by KITTEL, NESBITT and SHOCKLEY (*Phys. Rev.*, 1950, vol. 77, Mar. 15, pp. 839-40), the essential features of which are discussed and diagrammatically illustrated. The work reported gives strong confirmation of the mechanism proposed. Torque measurements on single crystals and electron micrographs prove that when the material is not heat-treated in a magnetic field the rods of precipitate formed during the treatment grow in the three <100> directions, the circles shown in the diagram below



Simplified permanent-magnet structure showing domain orientation.

(A) Without heat-treatment in magnetic field.

(B) With heat-treatment in magnetic field.

being the ends of the rod. This results in the matrix being cube-shaped, with its domain magnetization lying in a <011> direction in the (100) plane.

From this type of domain arrangement a residual induction of about 0·7 of saturation would be anticipated. This presumption was confirmed, since figures of approximately 9,000 gauss for residual induction and 13,000 gauss for saturation were obtained on an alloy not heat-treated in a magnetic field. When the structure is heat-treated in a field in the [001], a single easy direction of magnetization is established in the field direction, and the transverse precipitation is suppressed. This causes the large increase in residual induction of the alloy, and from this domain arrangement a value for residual induction practically equal to that for saturation would be expected. This was also confirmed by experiment, showing that residual inductions of about 13,000 gauss are obtained in Alnico 5 after heat-treatment in a magnetic field.

Moreover, according to the theory of fine particles, if the shape effect of the magnetic domains is increased by heat-treatment in a magnetic field, as is indicated by the electron micrographs and torque measurements, the coercive force of the alloy should increase. This, too, is borne out experimentally, since the coercive force of the single crystal was increased approximately 150 oersted by heat-treatment in a magnetic field.

Nickel-containing Permanent-Magnet Alloys in Physical Research Equipment

D. HADFIELD and D. L. MAWSON: 'Permanent Magnets for Spectrographs and Nuclear Physical Research.' *Brit. Jnl. Applied Physics*, 1952, vol. 3, June, pp. 199-202.

Until recent years, the requirement for high and constant magnetic fields in large air gaps had to be met by the use of bulky d.c. electro-magnets, with elaborate voltage-stabilizing devices and water-cooled coils. To-day, as a result of recent progress in permanent-magnet materials, field strengths of the same order of magnitude and considerably greater constancy can be obtained more efficiently with compact permanent magnets. The development of the anisotropic nickel-aluminium-cobalt-copper-iron alloys has been an outstanding factor in this progress.

Composite permanent magnets, embodying these alloys, are being used increasingly in equipment for research in many branches of applied physics. Particular applications discussed by the authors of this paper are for cosmic-ray traps, nuclear magnetic-resonance apparatus, mass spectrometers, and β-ray spectrographs. The design of a magnet for use in the last-named application is described in detail, with illustrations.

Magnetic Properties of Nickel-Cobalt-Iron Alloys (Perminvars)

H. J. WILLIAMS and M. GOERTZ: 'Domain Structure of Perminvar having a Rectangular Hysteresis Loop.' *Jnl. Applied Physics*, 1952, vol. 23, Mar., pp. 316-23.

Previous investigations of a Perminvar alloy (nickel 45, iron 30, cobalt 25, per cent.) heat-treated in a magnetic field, showed the material to have a very high maximum permeability and a rectangular loop. A study made in 1942, by KELSALL and GOERTZ of the Bell Telephone Laboratories, on effect of composition on the magnetic properties of Perminvars heat-treated in a magnetic field, showed that the alloy containing nickel 43, iron 34, cobalt 23, per cent. had the highest maximum permeability (415,000), after annealing for one hour at 1000°C., followed by cooling from the Curie temperature in a magnetic field of about 15 oersteds.

The aim of the work reported in the present paper was to investigate the domain structure of polycrystalline Perminvar ring specimens after heat-treatment in a magnetic field, to observe the manner in which this domain structure changes with an applied field, and to correlate these observations with the magnetic properties of the alloy. Magnetic materials having rectangular hysteresis loops are of practical value for mechanical contact rectifiers, and for memory-storage devices.

Domain patterns obtained with colloidal magnetite showed curved domain boundaries extending completely round the rings, forming circles concentric with them. Changes in magnetization were found to occur when an applied field causes the circular boundaries either to expand or contract, so that there is a change in the relative values of clockwise and counter-clockwise flux. A nucleus of reversed magnetization was formed by making a small notch in the specimen, and this decreased the coercive force and hysteresis loss by a factor of two. It was found that in a 180° domain boundary it was possible, by the application of a field of appropriate sign, perpendicular to the surface, to make the change in spin orientations which occurs in going from one side of the boundary to the other have a right- or left-hand screw relation. The effect of superposing an applied alternating field was also investigated, and an effective permeability of 4,000,000 was so obtained. Under these conditions the effective coercive force is decreased from 0·08 to 0·003 oersted.

Nickel-Iron Alloy Cores in Magnetic Amplifiers

F. BENJAMIN: 'Improvements Extend Magnetic-Amplifier Applications.' *Electronics*, 1952, vol. 25, June, pp. 119-23.

The article summarizes recent advances in design and use of magnetic amplifiers, emphasizing the important part played by the newer high-permeability nickel-iron alloys in making possible such developments. In the early days magnetic amplifiers employed saturable core reactors made of ordinary transformer-grade steel. Three-legged core construction was usual, and high-gain amplifiers necessarily consisted of a multitude of stages. Improvement of gain was later achieved by the use of grain-oriented silicon steels, and further advances and use for other applications led to the employment of such alloys as Mumetal, Supermalloy and molybdenum-Permalloy. A still later stage of development was the introduction of toroidal cores of tape, using grain-oriented 50-50 nickel-iron alloys characterized by high saturation flux density, and by

narrow and rectangular hysteresis loops, e.g., Deltamax, Hipernik V, Orthonol and other alloys. Rectifiers in magnetic-amplifier circuits are usually of the selenium type, and for some special purposes germanium is employed.

The author gives a description of typical applications in which high-gain magnetic amplifiers are now being used: their future is considered to be one of rapidly increasing usefulness. Systems consisting of a combination of magnetic amplifiers, transistors and dielectric amplifiers are among the developments now under investigation.

Properties of Iron-Nickel-Cobalt Alloys for Glass-to-Metal Seals

K. H. MAIRS: 'Fe-Ni-Co Alloys for Glass to Metal Seals.' *Jnl. of Metals*, 1952, vol. 4, May, pp. 460-4.

A general discussion of technical data in the literature (correlated with observations made by the author), relating to the influence of composition, heat-treatment and mechanical working, on the thermal-expansion characteristics, constitution and structure of iron-nickel-cobalt alloys of the Kovar, Fernico and related types. The following are among the conclusions drawn from a consideration of available data:—

The type of equilibrium diagram proposed by KASE (*Science Reports*, Tôhoku Imperial Univ., 1927, vol. 16, p. 491), which is reproduced in the present paper, is probably essentially correct, although it is doubtful whether the materials used were examined under equilibrium conditions, and the location of the phase boundaries is therefore open to question. The diagram is, however, a satisfactory key for explanation of the general behaviour of iron-nickel-cobalt alloys.

The formulae proposed by SCOTT (*Trans. Amer. Inst. Mining and Metallurgical Engineers*, 1939, vol. 135, p. 542: *Jnl. Franklin Inst.*, 1935, vol. 220, p. 733), for selecting alloy compositions in which Ar_3 transformations are suppressed to $-100°C.$, are not entirely satisfactory, because they do not recognize important factors such as mechanical stress and grain sizes. The comments of Scott on the influence of carbon in stabilizing the structure of these alloys have been experimentally demonstrated many times, but the presence of carbon in such alloys cannot be tolerated where they are used for sealing to or through glass, due to reactions between carbon and the various oxides in glass.

Work-hardening has an appreciable influence on the temperature at which the Ar_3 transformation takes place. For example, an annealed alloy which, on cooling, underwent Ar_3 transformation between 0° and $-10°C.$, was transformed 50 per cent. or more to martensite by plastic deformation at room temperature.

Grain size appears to exert an appreciable influence on the temperature of the Ar_3 transformation in the iron-nickel-cobalt alloys of the sealing-alloy range of composition. In some of the alloys the temperature of the transformation may rise with increasing grain size. Recrystallization takes place in the range 600°-700°C., producing a fine-grained material, of normal structure. At higher temperatures grain growth takes place rapidly.

Normal properties are to be anticipated in iron-nickel-cobalt alloys of this type if they are entirely austenitic and do not undergo crystallographic transformation. Abnormalities in microstructure, expansion characteristics or magnetic properties indicate a material which has undergone some degree of transformation to martensite. In such a form the alloys are irreversible and unsuitable for use in sealing.

Magnetostriction in High-Nickel Alloys

See abstract on p. 202.

X-Ray Fluorescent Analysis of Nickel and Nickel Alloys

See abstract on p. 199.

CAST IRON

Formation of Spheroidal Graphite in Cast Iron

F. HURUM: 'A Study of the Formation of Nodular Graphite.' *Amer. Foundrymen's Soc., Preprint* 52-75, May, 1952; 14 pp.

The paper reports work done in the Metallurgy Department, Norway Institute of Technology, Trondheim. On the basis of microscopical examination of S.G. iron produced by magnesium treatment, the author advances an original hypothesis to explain formation of spheroidal graphite.

Effect of Magnesium on Formation of Graphite

I. C. H. HUGHES: 'Some Effects of Magnesium on the Formation of Graphite in a Solidifying Cast Iron.' *Inst. Brit. Foundrymen, Paper* 1036, June, 1952; 18 pp.

Hypotheses which have been proposed to explain the mechanism of spheroidal-graphite formation are reviewed, as an introduction to a report of work on a cast iron containing 1 per cent. of nickel, examined in four conditions: magnesium-free, magnesium-treated, uninoculated, and ferrosilicon-inoculated. Cooling curves were determined, using samples of 150-gram weight, with a cooling rate controlled to simulate that of a 2-in. diameter sand-cast bar. The solidification sequence was studied by microscopical examination of 50-gram samples, quenched at various stages of solidification.

Production of Spheroidal-Graphite Cast Iron by Treatment with Metallic Magnesium

C. LONGARETTI and M. NORIS: 'A New Process for the Industrial Production of Nodular Cast Iron with Low Treatment Cost.'

Paper presented at International Foundry Congress, May, 1952: see also *Fonderia Italiana*, 1952, vol. 1, June, pp. 3-9.

The authors describe the method developed by Finsider,* which comprises treatment of molten cast iron by submerging in it compacts consisting of chips of magnesium or of Elektron scrap. The compacts are

* Financial Siderurgical Industry: the Governmental financial group which controls the nationalized Italian ferrous industry.

prepared by ramming the chips into the perforated head of a plunger, which is immersed in the iron. The magnesium vapour so generated issues from the perforations and bubbles through the iron, treating it safely and without explosive effects.

Treatment with Mischmetall for Neutralization of Interfering Elements in S.G. Iron

H. MORROGH: 'The Influence of Some Residual Elements, and their Neutralization, in Magnesium-Treated Nodular Iron.' *Amer. Foundrymen's Soc., Preprint* 52-79, May, 1952; 13 pp.

See also paper abstracted in *Nickel Bulletin*, 1952, vol. 25, No. 6, pp. 152-3.

This paper opens with a brief survey of previous literature dealing with the detrimental effects of trace elements on the production of spheroidal-graphite structures by the magnesium process. The various interfering elements are then considered individually, and experimental data are recorded showing the effects of these elements on the microstructure and mechanical properties of magnesium-treated iron. The elements studied in the investigation reported were lead, bismuth, antimony, tin, arsenic, aluminium, titanium and copper. It is shown that an addition of cerium (in the form of Mischmetall), subsequent to normal magnesium treatment, completely overcame any interfering effect produced by the elements in the ranges studied. The author emphasized the very small amounts of Mischmetall which suffice as a corrective, and this finding, together with other observations made, was confirmed in discussion presented by W. STEVEN and R. M. LAMB.

Comparison of Properties of S.G. Iron and of Malleable Cast Iron

C. C. HODGSON and C. S. JOHNSON: 'Some Experiments with Ductile Cast Iron.' *Metallurgia*, 1952, vol. 45, May, pp. 218-21.

This paper deals with experimental production of S.G. iron, on both a laboratory and a foundry scale, and with the properties of S.G. iron in the annealed condition. Effects of composition, on the mechanical properties of the material, are considered. Results of machining tests emphasize the reduction in the time required, and the improved surface obtained, in handling S.G. iron, by comparison with malleable. Data are also presented to demonstrate the ductility and toughness of the magnesium-treated iron.

See also next abstract.

Effect of Heat-Treatment on the Properties of S.G. Iron

C. C. HODGSON and W. FAIRHURST: 'The Annealing and Heat-Treatment of Ductile Cast Iron.' *ibid.*, June, pp. 283-8, 296.

The test castings used in this investigation were produced from 18-lb. high-frequency furnace melts, using a high-carbon, low-silicon, low-manganese base iron. The iron was treated with nickel-magnesium alloy.

Using standard annealing treatments producing a ferritic matrix structure, a study was made of the influence of silicon and of manganese, in the base iron, on impact value and microstructure. The results are presented in diagrams and tables. A further section of the investigation covered examination, by step-quenching, of the progress of transformation during furnace cooling, sub-critical annealing, and isothermal transformation.

Mechanical properties of oil-quenched and tempered S.G. iron are compared with those of the same material in the annealed condition: the influence of silicon is particularly discussed, (1) as affecting production of ferritic structure, and (2) in relation to mechanical properties. Suggestions are made for a 'preferred analysis' for S.G. iron to be used in the ferritic condition.

Properties and Applications of S.G. Iron

A. B. EVEREST: 'Engineering Properties and Applications of S.G. Iron.' Paper to 4th. International Mechanical Engineering Congress, Stockholm, June, 1952; 23 pp. Reprint issued by Mond Nickel Co., Ltd., as *Publn.* 603*.

This paper supersedes, and brings up to date, the paper of similar title presented in June 1950 at the Conference of the Institute of British Foundrymen, and subsequently reprinted as Mond Nickel Company Publication 455.

This later paper presents the most recent data on S.G. iron, in a form suitable for use by engineers and designers. Information which has appeared in the literature on all the mechanical and physical properties of as-cast and annealed S.G. iron is summarized in tabular form, and the properties of S.G. iron are compared with those of high-duty flake-graphite cast irons and of other cast irons and cast steel. A.S.T.M. specifications for S.G. iron are quoted, and brief reference is made to hot- and cold-working technique.

The second part of the paper is devoted to a review of the applications of S.G. iron: the discussion is supported by illustrations of castings made by foundries in various parts of the world, and covering a wide range of industries.

Properties and Uses of Nickel-containing Cast Irons

M. BALLAY: 'The Development of Engineering Grey Cast Irons: High-Strength Cast Irons.' Paper presented at 4th. International Mechanical Engineering Congress, Stockholm, June, 1952; 17 pp.

A review of the composition and properties of grey cast irons currently available for use in engineering applications in a wide range of industries. Brief consideration is given to the nature of the tests by which the characteristics of cast irons are assessed, and the main sections of the paper summarize the properties of plain and alloy cast irons, spheroidal-graphite irons, corrosion-resisting irons, those having special physical qualities, and those resistant to wear and abrasion. Throughout the paper the emphasis is on materials which offer to the engineer an increasingly wide choice for constructional and other purposes.

** We shall be pleased to supply a free copy of this publication.*

The review clearly demonstrates the progress which has been made in development of cast irons of all types during recent years.

Resistance of Nickel-Alloy Steels and Cast Irons to Fatigue Under Combined Stresses

See abstract on p. 211.

Ni-Resist in Insecticide Sprayers

'Power Sprayers Work Better Longer with Alloyed Parts.' *Nickel Topics*, 1952, vol. 5, No. 4, p. 7.

One of the more notable trends in modern agriculture is the increasing use of equipment for spraying soil, trees, and crops, to destroy parasitic insects, and to wipe out weeds and fungus growths. Considerable use is also being made of spraying methods for treatment of cattle and other live stock.

This article describes a sprayer of compact type, capable of being handled by one man, and readily mounted on a tractor or other vehicle for extensive operations, or for transport. The sprayer handles 4-6 gallons of liquid per minute, and is designed in such a way as to be suitable for use for many purposes.

Most of the solutions used for treatment are highly corrosive to metallic materials of many kinds, and in operation of the sprayer erosion or abrasion is also a factor, due to the use of slurries containing solid particles. In order to assure the corrosion- and erosion-resistance required for efficient working, Ni-Resist has been selected for the pump block of the model described, and the choice of this material has also obviated the need for use of a bronze bushing, due to excellent wear-resistance of Ni-Resist. Gears and connecting rod in the sprayer are of spheroidal-graphite cast iron, in order to ensure the toughness and strength needed to prevent breakage in service.

CONSTRUCTIONAL STEELS

Conservation of Alloy Steels

See leading article, pp. 190-193, of this issue of *The Nickel Bulletin*. A note intended to serve as an introduction to the Ministry of Supply Direction referred to in the leader is published in *Metallurgia*, 1952, vol. 46, July, pp. 31-2.

Production and Processing of Steel: Handbook

'The Making, Shaping and Treating of Steel.' Complete Revision, based on the Original Text by J. M. CAMP and C. B. FRANCIS. 6th Edn. *Published by United States Steel Co.*, Pittsburgh, Pa., June, 1951; 1584 pp. Price £4 0s. 0d.

This edition of the well-known textbook is no longer the exclusive work of any individual authors. The material has been revised, and in large part rewritten, by technical representatives of United States Steel Corporation subsidiary companies; it is the result of co-operative effort by many authors, editors and reviewers, supervised by research personnel of the United States Steel Company.

The information given, which is essentially practical in character, forms a compilation of past and present practices in the iron and steel industry, as summarized by the numerous authors in the light of their individual opinions and experience. An introductory chapter on the fundamental principles of chemistry and physics, as related to steelmaking, is followed by chapters on refractories; iron ores; fuels, fluxes and slags; manufacture of iron and steel; mechanical and thermal processing of steels in many forms; composition and properties of plain and low- and high-alloy steels, and mechanical testing.

Emergency Steels: American Iron and Steel Specifications

'Boron and Tentative Standard Steels.' *Metal Progress*, 1952, vol. 61, June, p. 96B.

List as of Mar. 5, 1952, including a large number of 'lean-triple-alloy' steels of boron-containing and boron-free types.

Specification for Nickel Nitralloy

AMER. SOC. TESTING MATERIALS: 'Proposed Tentative Specification for Alloy-Steel Bars for Nitriding.' Contained in Report of Committee A-1 on Steel; *A.S.T.M. Preprint* 2, June, 1952, pp. 32-6.

The specification covers four classes of steel bar for nitriding: classes A and D are general aluminium-chromium-molybdenum nitriding compositions, class B is a free-cutting grade containing selenium, and class C is a steel containing 3·25-3·75 per cent. of nickel (in addition to aluminium, chromium and molybdenum), to provide a material of high core strength.

Effect of Nickel on Rate of Nucleation and Rate of Growth of Pearlite

R. W. PARCEL and R. F. MEHL: 'Effect of Molybdenum and of Nickel on the Rate of Nucleation and the Rate of Growth of Pearlite.' *Jnl. of Metals*, 1952, vol. 4, July, *Trans. Amer. Inst. Mining and Metallurgical Engineers*, pp. 771-80; T.P. 3207E.

The materials used in this research were of the following types:—

(1) pure iron-carbon-molybdenum alloys;
(2) iron-carbon-manganese-molybdenum alloys (two groups);
(3) iron-carbon-nickel alloys;
(4) iron-carbon-manganese-nickel alloys.

Full compositions are given, together with particulars of the treatments used on the respective materials and the experimental methods of investigation employed for study of rate of nucleation, N, and rate of pearlite growth, G.

The alloys contained 0-0·77 wt. per cent. molybdenum and up to 2·95 wt. per cent. nickel. Influence of molybdenum on the interlamellar spacing was also measured.

The results show that both N and G are decreased by molybdenum and nickel, at all temperatures, and in all the materials studied. G was found to decrease by orders of magnitude when the interlamellar spacing increased by factors of only 2 or 3: G is therefore not determined primarily by the spacing.

G was observed to decrease exponentially with increase in alloy content: combined effects of several elements on G are found to be multiplicative. A change in the slope of the curve of log G vs. percentage molybdenum was found, coinciding with the appearance of the non-cementitic κ carbide. A similar, though less certain, change in slope was found for N. The evidence produced by these investigations is considered to be strongly in favour of a segregation of the alloying element concomitant with growth of pearlite, in the steels examined.

Influence of Applied Stress on Martensitic Transformation in High-Nickel Steel

S. A. KULIN, M. COHEN and B. L. AVERBACH: 'Effect of Applied Stress on the Martensitic Transformation.' *Jnl. of Metals*, 1952, vol. 4, June; *Trans. Amer. Inst. Mining and Metallurgical Engineers*, pp. 661-8; T.P. 3274 E.

The sensitivity of the martensitic transformation to strain has long been recognized, and it is well known that martensite formation can be induced by plastic deformation at temperatures below, and not far above, the M_s point. The exact rôle of elastic, as compared with plastic strains, and of the concomitant stresses, is not, however, completely understood. The present authors, after a brief discussion of earlier relevant investigations, report a study of martensitic transformation in steel containing nickel 20, carbon 0·5, per cent. This steel was selected because its normal martensitic transformation occurs in a convenient sub-zero temperature range, and the extent of isothermal martensite transformation is negligibly small, thereby minimizing possible complication from the time variable during stress studies.

The following summary is made of the conclusions drawn from the highly detailed experimental data presented:

'The martensitic transformation can be initiated by elastic stresses at temperatures above M_s. Hence the rôle of applied stress is not merely one of producing nuclei by plastic deformation.

'It is suggested that the rôle of applied stress at temperatures just above M_s is to supply critical strains to existing embryos. This makes it unnecessary to adopt the assumption that the austenite lattice becomes mechanically unstable at M_s.

'The normal strain, acting on a potential habit plane, has an important effect on the nucleation process, and therefore a critical resolved shear stress or strain cannot be regarded as a valid criterion for inducing the transformation.

'Shear strains and positive (tensile) normal strains acting on a potential habit plane promote the transformation, but negative (compressive) normal strains oppose it. Hence, strain energy, being independent of the sign of the normal strain, cannot provide a suitable criterion for the transformation.

'Based on the reaction-path theory, a combined strain criterion is presented, which takes into account the shear and dilatation components of the atomic displacements during the transformation, and which is consistent with the following observations:—

(*a*) M_s and M_b are raised by uniaxial tension.

(*b*) M_s is raised, but M_b is lowered, by uniaxial compression.

(*c*) M_s and M_b are lowered by triaxial and hydrostatic compression.

'Applied and residual stresses appear to be additive in their effect on the transformation.

'Yielding by slip or by the stress-induced transformation may be considered as competitive deformation processes. Either may precede the other, and either may influence the other.'

M_s = start of martensitic transformation.

M_b = temperature of martensitic 'burst' (see *Jnl. of Metals*, Sept. 1951; *Nickel Bulletin*, 1951, vol. 24, No. 11, p. 235).

Weldable Copper-Nickel-Molybdenum High-Strength Steels

F. NEHL: 'Possibilities for Further Improvement of High-Strength, Weldable Structural Steels.'

Paper presented at 4th. International Mechanical Engineering Congress, Stockholm, June, 1952; 16 pp.

Problems associated with the production of steels which combine high mechanical strength with good weldability are discussed, and a review is made of some methods which have been adopted to balance the somewhat conflicting requirements involved. Particular attention is directed to a range of heat-treatable copper-nickel-molybdenum steels containing traces of other modifying elements such as niobium, which have proved capable of giving the properties required in high-tensile steels, combined with good weldability. A typical composition is given as carbon less than 0·20, silicon 0·45, manganese 0·95, copper 0·90, nickel 0·80, molybdenum 0·18, per cent., with small amounts of carbide-forming elements. Cf. paper abstracted in *Nickel Bulletin*, 1952, vol. 25, No. 3, p. 71.

Sub-Zero Notch-Toughness of Nickel-Alloy Steels

W. B. SEENS, W. L. JENSEN and O. O. MILLER: 'Notch-Toughness of Four Alloy Steels at Low Temperatures.' *Proc. Amer. Soc. Testing Materials*, 1951, vol. 51, pp. 918-28; disc., pp. 929-30.

The paper presents data on the effect of temperature, within the range room temperature to −315°F. (−193°C), on notch-toughness, as revealed by the Charpy keyhole test, of three low-alloy and one medium-alloy types of steel which are of interest for commercial low-temperature service.

S.A.E. '2215' plate (A.S.T.M. 203-49T. grade A): carbon 0·16, nickel 2·34, per cent.

S.A.E. 2317 plate (A.S.T.M. 203-49T, grade D): carbon 0·13, nickel 3·37, per cent.

S.A.E. 2317, tube: carbon 0·17, nickel 3·45, per cent.

S.A.E. 4815 plate: carbon 0·15, nickel 3·32, molybdenum 0·25, per cent.

S.A.E. 2810, plate and tube: carbon 0·10, nickel 9·02, per cent.

The impact specimens were taken from ½-in. and 2-in. thick plates of all four steels, and from 0·24-in. or 0·30-in. wall tubing of the 2317 and 2810 steels. Each steel was tested in various conditions; full particulars are given of the heat-treatments.

The overall behaviour of the steels would rate them in the following order with respect to the temperature at which their notch-toughness first reaches a relatively low value, e.g., below 15 ft.-lb.:—

1. '2215' (highest temperature).
2. 2317 and 4815.
3. 2810 (lowest temperature).

This arrangement is in the order of increasing nickel content, but it is pointed out that this is only one of the factors responsible for increased notch-toughness at low temperatures. The notch-toughness of all the steels decreased gradually at first with fall in temperature, and in the three lower-alloy steels this gradual decrease was followed by a more abrupt drop at relatively low temperature.

No significant difference was found, in notch toughness, between specimens from the centreline of the plate and those from a location midway between centre and edge. Charpy values were considerably higher for longitudinal than for transverse specimens, except at the lowest temperatures in the range, where both types of specimen were relatively brittle. This difference is believed to be due to directionality resulting from straight-away rolling (no cross rolling was applied). Notch-toughness at low temperatures was greatly improved by suitable heat-treatment. In general, normalized plate gave better values than hot-rolled plate, and quenching-and-tempering treatment resulted in further improvement.

The effect of thickness of plate was found to depend on the hardenability of the steel and the heat-treatment which it had undergone. Specimens from ½-in. plate showed greater toughness at low temperature than those from 2-in. thick plate, except when hardenability was such that the thicker plate responded to heat-treatment as effectively as the thinner plate.

The effect of fall in temperature on notch-toughness of half-size Charpy specimens from tubing was less than for full-size specimens from 2-in. or heavier plate. This difference is considered to be due partly to the difference in size of the specimen, and, to a lesser extent, to differences in rate of cooling for the same nominal heat-treatment.

Mechanical Testing of Nickel-Alloy and Other Structural Steels

AMER. SOC. TESTING MATERIALS: 'Proposed Tentative Methods and Definitions for Mechanical Testing of Structural Steel.' Contained in Report of Committee A-1 on Steel; *A.S.T.M. Preprint* 2, June, 1952, pp. 15-20.

The methods and definitions proposed apply to the following specifications issued by the American Society for Testing Materials, relating to steels of various types: A 6, 7, 8, 94, 113, 131, 141, 195, 242, 283, 284 and 328. The schedule covers equipment, test-pieces and procedure for determination of tensile and yield strength, elongation and reduction of area, and equipment and method for bend testing.

Resistance of Nickel-Alloy Steels and Cast Irons to Fatigue Under Combined Stresses

H. J. GOUGH: 'Some Experiments on the Resistance of Metals to Fatigue under Combined Stresses.' *Ministry of Supply, Aeronautical Research Council Monograph R. and M.* 2522, 1951; 141 pp. Published by His Majesty's Stationery Office, 1951.

The basic object of the investigation reported was an experimental study of the fatigue-resistance of metals to combined flexural and torsional stresses, of the types to which many engineering components, particularly crankshafts, are subjected in practice. Four independent variables were employed in the tests: reversed bending stresses, reversed torsional stresses, static bending stresses, and static torsional stresses superimposed on these cyclic stresses. Supplementary static, impact, and simple fatigue tests, with chemical analysis and metallurgical examination, were made on all the materials. The scope of the work covered in each part of the investigation is indicated below:—

Part I (H. J. GOUGH and H. V. POLLARD) describes a comprehensive research on the fatigue behaviour of a selection of engineering steels (including plain carbon, nickel, nickel-chromium, nickel-chromium-molybdenum, nickel-chromium-molybdenum-vanadium and chromium-vanadium types), and two alloy cast irons (Silal, a relatively brittle material, and Nicrosilal, representing a comparatively ductile cast iron). The tests were made under combined bending and torsional stresses alternating in phase, the mean stress of both types of stress cycle being zero in every case. A special type of testing machine developed for this part of the research is described. Heat-treatments applied to the various steels were selected to permit examination of the influence, on fatigue properties, of four types of microstructure: ferrite-and-pearlite, pearlite, a uniform matrix containing spheroidized cementite, and hardened-and-tempered structure.

Part II (with W. J. CLENSHAW) describes study of the resistance of a nickel-chromium-molybdenum-vanadium aircraft steel to combined fatigue stresses, in which the influence of all four of the variables mentioned above was investigated. A second combined-stress fatigue-testing machine, designed for this section of the work, is described.

Fatigue Properties of Nickel-Chromium-Molybdenum Steel

J. T. RANSOM and R. F. MEHL: 'The Statistical Nature of the Fatigue Properties of S.A.E. 4340 Steel Forgings.' *Amer. Soc. Testing Materials, Preprint* 87, June, 1952; 19 pp.

The Metals Research Laboratory of the Carnegie Institute of Technology has been engaged for more than ten years in a systematic study of the mechanical properties of forging steels. It has been shown that reduction of area in the transverse direction in plain-carbon and alloy steel forgings exhibits statistical variability, and the factors which affect such variability have been investigated in detail. Reference is directed to relevant reports already published.

The present paper records study of the statistical

nature of the fatigue properties of S.A.E. 4340 nickel-chromium-molybdenum steel gun tubes. Forgings of both high and low quality (assessed on the basis of transverse tensile reduction of area) were tested, specimens being taken in both longitudinal and transverse directions.

Variability of fatigue properties of even high-quality forgings was found to be greater than is generally estimated from the results of conventional non-statistical testing: this was especially true of the endurance limit.

J. T. RANSOM and R. F. MEHL: 'The Anisotropy of the Fatigue Properties of S.A.E. 4340 Steel Forgings.' *Amer. Soc. Testing Materials, Preprint* 93, June, 1952; 9 pp.

The materials used in this investigation were from the same heats as those used in the study reported in the paper abstracted above. Tests were made to determine the effect of direction of measurement on the fatigue characteristics. The average transverse endurance limit was found to be 84 per cent. of the average longitudinal limit in the steel showing high reduction of area in the transverse direction, while the ratio was only 68 per cent. in the specimens showing low reduction of area. Life to failure was similarly anisotropic, showing a like relation to reduction of area in the transverse direction. It is concluded that the anisotropy of fatigue properties, like that observed in reduction of area, is determined, in large measure, by the presence of fragmented stringer-type inclusions.

Atmospheric Corrosion-Resistance of Low-Alloy Nickel-containing Steels

See abstract on p. 222.

Low-Alloy Manganese-Nickel-Molybdenum Steel for Locomotive Parts

J. F. SEWELL: 'An Alloy Steel for Locomotive Motion Parts.' *Railway Steel Topics*. 1952, vol. 1, No. 1, pp. 28-32.

For applications such as pistons and coupling and connecting rods, which are some of the most highly stressed of locomotive components, it is generally recognized that the use of alloy steels can have marked advantages. Their excellent tensile and fatigue properties, coupled with high toughness and uniformity of properties across the sections, minimizes the danger of breakage of rods, and the reduction in weight resulting from their use for reciprocating parts materially lessens 'hammer blow' and 'nosing' effects.

This article describes the properties, treatment, and uses of a general-purpose low-alloy steel, 'Tormanc Special', developed, some years before the war, for railway and heavy-engineering use. The steel contains about 1½ per cent. manganese, with small amounts of nickel and molybdenum, and conforms to B.S. specification En 13. Due to its low carbon content (0·15-0·25 per cent.) no special precautions are required in forging and heat-treatment, and although optimum mechanical properties are obtained by oil-hardening and tempering, simple normalizing and tempering is satisfactory. Since the steel is completely free from tendency to temper-brittleness, it may be air-cooled from the tempering temperature. The properties given in the table below are quoted for specimens of various sections (on material taken from a position midway between the outside and centre of the section, except in the case of the 1⅛-in. dia. section, where the test pieces were machined concentrically).

As an indication of the wide latitude in treatment which can be tolerated by this steel without undue impairment of properties, some figures are given for specimens which had been subjected to extremes of incorrect treatment likely to be encountered in commercial practice. In all cases a simple tempering treatment proved sufficient to restore the normally good properties of the steel. Figures cited for fatigue ratio and fatigue limit for Tormanc Special steel demonstrate that in this respect also it is of a grade particularly suitable for use in railway and other engineering applications. A further advantage is that it is easily weldable: excellent properties are obtained after electric butt welding, it being understood that heat-treatment after welding is necessary to restore the structure. Provided that the carbon content is kept below 0·20 per cent. and that in welding heavy sections pre-heating is carried out, Tormanc Special is capable of being welded also by gas and arc processes.

Treatment	Section	Maximum Stress t.s.i.	Yield Point t.s.i.	Elongation %	Reduction of Area %	Izod Impact ft.-lb. Average
Normalized and tempered 880°C. a.c. 650°C. a.c.	1⅛-in. dia.	45·6	39·6	24·0	63·6	86
	2¼-in. square	43·2	35·6	27·0	66·0	99
	4-in. square	42·7	33·2	26·0	61·6	87
	6-in. square	41·7	31·5	27·0	59·2	83
Oil-hardened and tempered 880°C. o.q. 650°C. a.c.	1⅛-in. square	51·9	45·7	22·0	63·6	82
	2¼-in. square	47·6	39·4	23·5	68·0	93
	4-in. square	44·6	37·7	24·5	61·5	87
	6-in. square	42·9	35·5	24·5	59·2	85

Heat-Treatment of Nickel-Alloy Steel Gears

'Heat-Treatment of Steel Gears: New Plant Installed at Rochester.' *Metal Treatment*, 1952, vol. 19, June, pp. 251-4.

In order to ensure an uninterrupted supply of gears for graders and other products of their works, Blaw Knox, Ltd. have equipped a modern gear-cutting shop and installed plant incorporating up-to-date electrical furnaces suitable for application of the various types of heat-treatment required for such parts. The main items in the heat-treatment shop are described in this article, which includes a diagram showing the layout of the shop. The steels used range from plain types, of the En 32 grade, through to the various nickel-alloy steels used for gears of varying size, e.g., En 34 to En 39. Details are given of gas-carburizing operations applied to some of these steels.

Nickel-Alloy Steel for Rings for Reduction Gears

AMER. SOC. TESTING MATERIALS: 'Proposed Revised Tentative Specification for Carbon and Alloy Steel Forgings for Rings for Reduction Gears.' Contained in Report of Committee A-1 on Steel; *A.S.T.M. Preprint* 2, June, 1952, pp. 42-5.

The specification covers normalized-and-tempered, and quenched-and-tempered carbon and alloy steel forged or rolled rings for main reduction gears. It may also be applied to ring forgings for auxiliary drives. The nickel-alloy steel included is of the following composition: carbon 0·35-0·45, manganese 0·55-0·90, phosphorus 0·050 max., sulphur 0·050 max., silicon 0·15 min., nickel 1·65-2·00, chromium 0·60-0·90, molybdenum 0·20-0·30, per cent.

Volumetric Determination of Nickel in Steel: Use of Versenate in Titration

W. F. HARRIS and T. R. SWEET: 'Volumetric Determination of Nickel in Steel.' *Analytical Chemistry*, 1952, vol. 24, June, pp. 1062-3.

Following a brief review of relevant earlier literature, the authors make reference to work by SCHWARZENBACH, on formation of organic complexes with metal ions. In a paper in *Helvetica Chimica Acta*, 1946, vol. 29, p. 812, this author and his colleagues showed that calcium may be titrated with disodium dihydrogen ethylenediamine tetraacetate (Versenate), using murexide as the indicator. He also pointed out that murexide may be used as indicator for a large number of other metal ions, including nickel (*ibid.*, 1949, vol. 32, p. 1314). The method of titration of metals with Versenate, using a dye to indicate the end-point, has been successfully applied to determination of hardness in water, and is being widely used for this purpose.

In the procedure described by the authors of the present paper, nickel which has been separated by the dimethylglyoxime precipitation is titrated with a standard solution of Versenate in the presence of murexide. The nickel dye complex has a yellow colour, whereas when uncombined with nickel the dye is purple. At the end-point all the nickel has combined with the Versenate, and the colour of the solution changes from yellow to purple. Full details of procedure are given.

Copper, cobalt, manganese, chromium, and iron do not interfere when present in the quantities usually found in steels or cast irons. Some recommendations are made for procedure to prevent interference by abnormally high percentages of some of these elements, and for overcoming difficulties associated with the presence of a large amount of ammonium salts in the solution at the time of titration.

The authors urge that the method described has certain advantages over the classical gravimetric procedure and other existing volumetric methods, e.g., if insoluble matter is present it is not necessary to filter the solution before the dimethylglyoxime precipitation; a large excess of dimethylglyoxime has no unfavourable effect, and therefore less care is required in operation; the standard Versenate solution is easily prepared, and is stable.

HEAT- AND CORROSION-RESISTING ALLOYS

Creep-Rupture Tests on Nickel-Alloy Steel Sheet

G. V. SMITH, E. J. DULIS and E. G. HOUSTON: 'Creep-Rupture of Several Sheet Steels.' *Proc. Amer. Soc. Testing Materials*, 1951, vol. 51, pp. 857-68.

Although many elevated-temperature applications involve the use of metals and alloys in the form of sheet or strip, the majority of creep and creep-rupture data have been obtained on bar or plate stock. In view of the fact that properties of sheet can differ significantly from those of bar or plate stock at room temperature, and of the proved influence of atmosphere on creep-rupture properties (which is influenced, *inter alia*, by ratio of surface area to volume), the authors made an investigation specifically designed to provide data on behaviour of sheet material under creep-rupture test.

The chemical compositions of the steels studied are shown in the table below:—

Type	C %	Mn %	P %	S %	Si %	Ni %	Cr %	Mo %
316	0·046	1·53	0·022	0·010	0·32	12·34	16·94	2·20
309	0·09	0·61	0·023	0·010	0·27	7·49	17·35	—
4608	0·09	0·35	0·010	0·010	0·13	1·57	—	0·21

The 316 steel had been hot-rolled to 0·050-in. gauge, annealed and pickled; the annealing treatment was 6½ min. at 1975°-2000°F. (1077°-1093°C.) and air-cooling. The 17-7 (Type 309) steel was supplied in 0·050-in. sheet, in both the annealed and the half-hard conditions; the annealed material had been heated 6½ min. at 1950°F. (1063°C.), air-cooled and de-scaled, while the half-hard material received a final cold-rolling of about 25 per cent. reduction in thickness after such annealing. All the steels were tested in the longitudinal direction.

The annealed Type 316 was tested at 1100°, 1300° and 1500°F. (593°, 704° and 815°C.); annealed and half-hard 17-7 (Type 309) at 600° and 1100°F. (315° and 593°C.), and cold-rolled 4608 at 600°F. (315°C.) only. A detailed description is given of grips specially designed for testing sheet or strip in creep-rupture.

The test results, which are fully tabulated, and correlated with observations on the structure of the steels, indicate, in the longitudinal direction, appreciable superiority of annealed and half-hard 17-7 steel at 600°F. (315°C.) and for relatively short rupture times at 1100°F. (593°C.). With increase of rupture time at 1100°F. (593°C.) the superiority of the cold-worked metal is lessened, although it is still obvious at 5,000 hours.

D. PRESTON: 'Exploratory Investigation of High-Temperature Sheet Materials.' *Amer. Soc. Testing Materials, Preprint* 85, June, 1952; 24 pp.

This paper also deals essentially with high-temperature materials in sheet form: it reports work sponsored by the Aviation Panel of the A.S.T.M.-A.S.M.E. Joint Committee on Effects of Temperature on Properties of Metals.

Nine alloys were investigated: their compositions are shown in the table below. They include three iron-base strain-hardening types, three iron-base age hardening alloys, and three cobalt-base alloys which are used in the annealed condition. Creep behaviour, stress-rupture properties, and tensile and yield strengths were determined on these materials, at temperatures within the range room temperature to 1800°F. (980°C.). Metallographic examination was also made. Fatigue and thermal-shock data for these materials will be reported, under the same project, at a later date.

The results of the tests are shown in tabular and graphical form, providing typical reference data. Among the points selected for special comment are the following:—

The room-temperature properties of strain-hardened 19-9 DL, H.S. 88 and Timken 16-25-6 do not indicate satisfactory formability. The high-temperature strength of H.S. 88, in creep and stress-rupture, is exceptionally high in view of its relatively low alloy content.

At 1200° and 1350°F. (648° and 733°C.) the creep strength of Discaloy 24 is appreciably higher than that of the other precipitation-hardened alloys studied.

On the basis of short-time strength there is no advantage in using the cobalt-base alloys studied at temperatures of 1500°F. (815°C.) or below.

Influence of Cold Work on Creep-Resistance

D. N. FREY, J. W. FREEMAN and A. E. WHITE: 'Fundamental Effects of Cold-Working on Creep Properties of Low-Carbon N-155 Alloy.' *Nat. Advisory Committee for Aeronautics, Tech. Note* 2472, Oct., 1951; 45 pp.

This is a fuller report of the work dealt with in the paper by FREY and FREEMAN, published in *Journal of Metals*, 1951, vol. 3, Sept., pp. 755-60: see *Nickel Bulletin*, 1951, vol. 24, No. 11, pp. 242-3.

Chemical Compositions of Sheet Alloys Tested

Alloy	C %	Cr %	Ni %	Mo %	Co %	Cb %	Ti %	Si %	S %	P %	Mn %	W %	Fe %	Others %
Timken	0·09	15·84	25·25	6·40				0·42	0·015	0·021	1·76		bal.	N_2=0·167
19-9 DL annealed	0·27	19·28	9·99	1·35		0·50	0·30	0·41	0·009	0·017	1·22	1·43	bal.	
19-9 DL cold-rolled	0·29	18·65	8·97	1·34		0·54	0·30	0·54	0·010	0·019	1·15	1·47	bal.	
H.S. No. 88 ..	0·07	12·62	15·04	2·42			0·50	0·52	0·006	0·013	1·40	0·84	bal.	B =0·14
Discaloy 24 ..	0·036	13·50	26·20	3·91			1·61	1·00			1·38		bal.	Al =0·11
Tinidur 1650 ..	0·04	14·70	26·10				2·26	0·73	0·015	0·020	1·00		bal.	Al =0·15
Tinidur 1875 ..	0·04	14·70	26·10				2·26	0·73	0·015	0·020	1·00		bal.	Al =0·15
A-286	0·07	15·80	26·10	1·39			1·59	1·00	0·010	0·014	1·62		bal.	Al =0·14 V =0·26
L-605	0·08	21·11	10·84		bal.			0·61	0·006	0·010	1·64	15·54	1·60	N_2=0·03
V-36	0·27	24·70	19·29	4·39	bal.	1·71		0·18	0·017	0·013	0·86	2·31	1·87	
WF-31	0·156	20·34	9·93	2·61	bal.		1·03	0·42	0·016	0·009	1·42	10·69	4·13	

Damping Capacity, Elasticity and Fatigue-Resistance of Nickel-containing High-Temperature Materials

B. J. LAZAN and L. J. DEMER: 'Damping, Elasticity and Fatigue Properties of Temperature - Resistant Materials.' *Proc. Amer. Soc. Testing Materials*, 1951, vol. 51, pp. 611-46; disc., pp. 647-8.

The work reported in this paper is part of a long-range test programme on high-temperature materials, dealing with their damping, elasticity and fatigue properties at engineering stress levels. Experimental data presented were obtained by tests on a newly developed rotating-beam fatigue-testing machine permitting continuous measurement of the damping energy and dynamic modulus of elasticity, during fatigue test. Materials tested and temperatures of test:—

S. 816. Complex cobalt-nickel-chromium-base alloy containing molybdenum, tungsten and niobium (r.t., 900° and 1600°F.: r.t., 482° and 871°C.).

Inconel X. Precipitation-hardening nickel-chromium-base alloy containing niobium, titanium and aluminium (r.t. only).

Chromium Steel. Type 403, containing 12·67 per cent. chromium (r.t. and 500°F.: r.t. and 260°C.).

Low-C N-155 Alloy. 20-20-20 nickel-chromium-cobalt-iron alloy containing molybdenum, tungsten and niobium (1500°F.: 815°C.).

Molybdenum. (r.t. and 900°F.: r.t. and 482°C.).

Molybdenum-Tungsten Alloy (98-2%). (r.t. and 900°F.: r.t. and 482°C.).

Copper-impregnated Iron. (r.t. and 500°F.: r.t. and 260°C.).

For all the materials and at all the temperatures used, the energy dissipated by damping increases rapidly with stress at values close to the fatigue strength of the material. During a constant reversed cyclic stress test the damping energy may decrease, remain unchanged, increase, or have a varying pattern, as the number of stress cycles is increased. In general, the changes in dynamic modulus of elasticity are reciprocal to the changes in damping energy. *S-N* data indicate that, in general, the curves tend to become flatter as temperature rises. The elevated-temperature properties of temperature-resistant materials may be lower than, equal to, or greater than, the room-temperature values.

Effect of a Notch and of Hardness on High-Temperature Strength of Nickel-Chromium-Iron Alloy

F. C. HULL, E. K. HANN and H. SCOTT: 'Effect of a Notch and of Hardness on the Rupture Strength of 'Discaloy'.' *Amer. Soc. Testing Materials, Preprint* 75, June, 1952; 10 pp.

Certain critical components of jet engines and gas turbines, such as turbine rotors, require materials of low notch-sensitivity at service temperatures of the order of 1000°-1350°F. (538°-735°C.). The materials suitable for use in this intermediate temperature range fall broadly into two categories: (1) those depending on the introduction of hot-cold work for increasing their mechanical strength, and (2) those responsive to precipitation-hardening treatments. One typical alloy of the latter group is considered in this paper, Discaloy, of which the nominal composition is as follows: nickel 25, chromium 13, molybdenum 3, titanium 1·4-2·4, manganese 0·8, silicon 0·8, aluminium less than 0·4, carbon less than 0·1, per cent., balance iron.

The effects of hardness, as varied by percentage of titanium present, are related, in this paper, to the behaviour of the material in the presence of a notch. Creep-rupture and notched-bar rupture tests were made at 1000° and 1200°F. (538° and 648°C.). The rupture strength of a plain bar of this material reached a maximum at a titanium-hardener content producing 2 per cent. rupture strain, and the notched-bar strength exceeded the plain-bar strength in material in which the creep specimen had more than 5 per cent. rupture strain. Close control of the titanium content is necessary to obtain the optimum combination of plain- and notched-bar rupture strength. Creep ductility was found to diminish fairly consistently with increasing hardness, to a value of about 3 per cent. elongation and 4 per cent. reduction of area at the strength maximum.

It is recommended that a standard test specimen be adopted for notched-bar testing of heat-resisting alloys. A form considered optimum is proposed.

Effect of Shape of Notch on Rupture Strength of High-Temperature Alloys

E. A. DAVIS and M. J. MANJOINE: 'Effect of Notch Geometry on Rupture Strength at Elevated Temperatures.' *Amer. Soc. Testing Materials, Preprint* 78, June, 1952; 21 pp.

The authors report results of creep-rupture tests on notched and plain bars of selected high-temperature materials, including data showing the effect, on rupture time, of varying the sharpness of the notch with constant depth of notch and shank diameter, and of varying the depth of notch with constant notch sharpness and stress. The effect, on notch-sensitivity, of the following variables was also determined: stress level, grain size, hardness, ductility, and heat-treatment.

The materials used were typical high-temperature alloys, some chosen for their strength and hardness, some on account of their ductility, and some because design data on them had been specifically requested. The general nature of the alloys is indicated below:—

Refractaloy 26 (complex nickel-chromium-cobalt-iron precipitation-hardening alloy which can be heat-treated to produce various combinations of hardness and ductility. The alloy was tested in three different conditions).

Steel containing chromium 12, *tungsten* 3, *per cent.* (selected because of its ductility and its stability at test temperature after a treatment specifically chosen to ensure this characteristic).

K 42*B* (precipitation-hardening alloy containing, as its main constituents, nickel, cobalt, chromium and iron. It differs from Refractaloy 26 in that it contains no molybdenum. It was tested in two conditions).

19-9 *DL* (an 18-8 chromium-nickel steel containing small additions of tungsten, molybdenum and niobium).

Consideration of test results, and examination of the structure of the test specimens, led to the following conclusions:—

Metals with high un-notched ductility exhibit a 'strengthening effect' for specimens with notches as sharp as can be ground accurately. The strengthening effect diminishes, and notch-sensitivity increases, as ductility decreases. For materials showing 10 per cent. or less un-notched elongation the notch effect may be strengthening or weakening, depending on the sharpness of the notch. Notch-sensitivity increases with sharpness of notch above a certain sharpness, and this critical sharpness increases with increase in ductility. Materials showing the same ductility do not necessarily have the same degree of notch-sensitivity.

For the same un-notched ductility or hardness, the notch-sensitivity of an alloy increases with increasing grain size. Stress level did not appreciably affect the relative notch-sensitivities of the alloys used in this investigation: there is only a slight indication that notch-sensitivity increases with decreasing stress. No effect of size was observed when the root area was varied by 36 per cent.

In a notched specimen under constant load, the time for initiation of a crack which will propagate is much longer than the time required for this crack to travel across the minimum section. The initial failure probably starts near the surface, at the root of the notch, and generally propagates along the grain boundaries.

Thermal Conductivity of Nickel and Nickel Alloys at High Temperature

C. L. HOGAN and R. B. SAWYER: 'The Thermal Conductivity of Metals at High Temperature.' *Jnl. Applied Physics*, 1952, vol. 23, Feb., pp. 177-80: *corrigendum, ibid.*, May, p. 600.

The Forbes bar method, the principles of which are described, was modified and adapted to the measurement of thermal conductivity of a series of metals and

Temperature °C.	Inconel X	Nickel	Nickel-Chromium Steels			Chromium Steel 446	1010 Steel
			303	310	347		
Thermal Conductivity: Calories (cm. sec. °C.)							
0	0·032	0·174	0·034	0·031	0·046	0·054	0·173
100	0·038	0·156	0·036	0·034	0·049	0·057	0·163
200	0·043	0·138	0·038	0·039	0·053	0·061	0·153
300	0·048	0·120	0·042	0·044	0·056	0·065	0·144
400	0·054	0·114	0·047	0·048	0·061	0·068	0·136
500	0·060	0·121	0·051	0·054	0·066	0·072	0·130
600	0·065	0·128	0·055	0·060	0·070	0·076	0·123
700	0·073	0·136	0·059	0·066	0·075	0·080	0·117
800	0·081	0·143	0·064	0·072	0·081	0·084	0·111
900	0·089	0·150	0·068	0·078	0·087	0·087	—
Electrical Conductivity: (mho. cm.) $\times 10^{-4}$							
0	—	11·3	1·38	—	1·27	1·75	—
100	0·814	7·56	1·25	0·999	1·18	1·44	4·30
200	0·804	5·12	1·13	0·951	1·11	1·25	2·82
300	0·794	3·87	1·05	0·908	1·07	1·12	2·05
400	0·784	2·87	0·988	0·870	1·03	1·02	1·60
500	0·774	2·62	0·940	0·841	1·00	0·940	1·20
600	0·764	2·40	0·900	0·818	0·984	0·880	0·95
700	0·770	2·25	0·870	0·800	0·967	0·840	0·80
800	0·782	2·10	0·846	0·785	0·950	0·820	0·70
900	0·795	2·02	0·824	0·771	0·933	0·810	—

alloys in the range 25°C.-1000°C. The authors make a mathematical analysis indicating the error involved by assuming plane isothermals in the sample. Thermal and electrical conductivity values for Inconel X, nickel, Types 303 and 310 nickel-chromium stainless steels, 446 straight-chromium steel, and 1010 carbon steel are shown in the table on p. 216.

The values found by the authors are discussed in relation to the theory presented by WILSON and by MAKINSON (*Proc. Cambridge Phil. Soc.*, 1937, vol. 33, p. 371, and 1938, vol. 34, p. 474).

Nickel-containing Electrical-Resistance Materials

See abstract on p. 202.

Effect of Softening and Hardening Temperatures on Valve Steel

B. CINA: 'Microstructural Changes in the High-Alloy Valve Steel XCR.' *Jnl. Iron and Steel Inst.*, 1952, vol. 171, July, p. 229-37.

Steels containing chromium 24, nickel 5, molybdenum 2·5, carbon 0·45 per cent. retain a high degree of hardness at temperatures of 500°C. and above, and are used for internal-combustion engine valves. This paper describes a study of the microstructural characteristics of a representative steel of this type (XCR), as influenced by variations in the softening and hardening temperatures.

As-rolled material was heated for one hour at 1050° or 1150°C., followed by water quenching, to eliminate possible work-hardening effects and to facilitate interpretation of subsequent microstructural changes. Half-inch long sections of the bar in the two softened conditions were hardened by treatments at 50°C. intervals in the range 300°-950°C., followed by water-quenching. Samples were held for periods up to one month at temperatures between 475° and 800°C. and for at least one week at all other temperatures. Details are given of the polishing and etching methods used for preparing the specimens for microscopical and X-ray examination. Vickers hardness tests were also made on all the specimens, using a 30-kg. load.

Full details are presented of the microstructure before hardening, microstructural changes accompanying hardening, and effect of furnace-cooling and water-quenching from the softening temperature. Results of microscopic examination and X-ray study are closely correlated, and an extensive series of photomicrographs illustrates the observations made. Hardening effects under the various treatments are diagrammatically shown. The conclusions drawn are summarized below:—

'As quenched from softening temperatures of 1050° or 1150°C. the steel consists of equal proportions of δ-ferrite and austenite, with undissolved chromium carbides occurring mainly in the austenitic zones. Hardening at temperatures between 650° and 900°C. causes the σ phase to form primarily from the δ-ferrite, and a linear relationship has been found between hardness and the percentage of σ. Maximum hardness is attained between 750° and 850°C. The formation of σ is accompanied by complex diffusion processes, leading to the transformation of δ-ferrite to austenite (γ′) at the hardening temperature, and to the transformation of the original and new austenitic phases to α-ferrite on quenching. The prior-softening temperature determined the rate of σ formation, the rate of transformation δ-ferrite $\rightarrow\gamma'$, and the associated diffusion processes and reactions. A secondary hardening effect was observed at 300°-600°C., at a maximum between 475° and 500°C., although σ could not be detected in any of these samples. The mode of this 475°C. hardening was different from that observed at 650°-900°C., and an over-ageing effect was found at 550°C.'

Rapid Softening Treatments for Austenitic Nickel-Chromium Steels

F. A. HODIERNE and C. E. HOMER: 'The Rapid Softening of Cold-Drawn Austenitic Stainless Steels.' *Jnl. Iron and Steel Inst.*, 1952, vol. 171, July, pp. 249-53.

The research reported was initiated to provide a basis for applying induction heating to the softening of cold-drawn stainless-steel tubes. The effects of short times of heating, on five austenitic stainless steels, were studied, and variation in properties and structure of the steels, as a function of heat-treatment in the range 500°-1350°C., was investigated. As a result of the observations reported, recommendations are made on times and temperatures for rapid heat-treatment of the steels. The materials used were of the compositions given in the table below.

The conditions recommended for rapid softening are as follows:—

'It is assumed that the cold-worked steel is to receive a final softening treatment, and that it is to be used in conditions requiring optimum corrosion-resistance. The material should be fully softened, with an average grain size, and must be free from precipitated chromium-rich carbides, especially at the grain boundaries. Although the latter point refers especially to the unstabilized steels, carbide in any form should be kept

Steel No.	C %	Si %	Mn %	Cr %	Ni %	Mo %	Ti %	Nb %
1	0·115	0·52	0·41	18·93	8·90	0·11	0·018	Nil
2	0·10	0·77	0·28	18·58	8·79	0·09	0·87	Nil
3	0·070	0·24	0·41	18·38	8·42	2·78	0·02	Nil
4	0·10	0·53	0·76	18·55	12·73	Trace	0·022	1·05
5	0·079	1·49	0·78	24·61	20·90	0·06	0·02	Nil

to a minimum, so as to ensure optimum corrosion-resistance. The ferrite content should also be kept as low as possible, since published information indicates that it can affect corrosion-resistance under some conditions. The σ phase should be absent, as it has an adverse effect on ductility and can lower the corrosion-resistance. To meet these requirements with ordinary times of heating, steel manufacturers recommend softening at 1050°C., followed by rapid cooling.

'The results of the present investigation show that rapid heating followed by immediate quenching does not lead to intercrystalline corrosion, so long as the temperature reached is high enough. The optimum treatment conditions are therefore determined by the need for obtaining satisfactory mechanical properties (indicated here by hardness and grain size), together with absence of σ and minimum ferrite and free carbides. The presence of some free carbide in the 18/13/1 and 25/20 steels is a permanent structural feature, and must be expected whatever softening treatment is applied.

'The use of very short times of heating necessitates a slight increase in softening temperature, to ensure that precipitates are redissolved and to give about the same hardness and grain size as ordinary times of heating. It is therefore recommended that with a time of heating to temperature of 5-6 sec., followed by immediate quenching, the following softening temperatures should be employed:—

Straight 18/8	1100°-1150°C.
Ti-stabilized 18/8	1100°-1150°C.
Mo-bearing 18/8	1100°-1150°C.
Nb-stabilized 18/13	1125°-1175°C.
25 Cr/20 Ni	1125°-1175°C.

'The optimum temperature ranges for other compositions are probably similar. It is important to ensure that material to be softened does not contain massive σ or carbide, from incorrect treatment at an earlier stage of manufacture. Such massive constituents, once formed, are very difficult to take into solution, and would not be dissolved in a rapid-heating operation of a few seconds. Apart from such exceptional cases, the recommended treatment should give material with satisfactory characteristics.'

Use of the Life-Test Method for High-Temperature Oxidation Tests

A. DE S. BRASUNAS and H. H. UHLIG: 'Oxidation of Alloys by the Wire Life Test Method.' *A.S.T.M. Bull.*, 1952, No. 182, May, pp. 71-5.

The authors report tests made by a life-test method modified from the A.S.T.M. standard procedure covered by specification B 76-39: for description see *A.S.T.M. Bulletin*, 1949, No. 161, p. 31. The specific object of the present tests was rapid evaluation of alloys, and of the efficacy of various surface treatments, for prevention of high-temperature oxidation. The advantages and limitations of the life test for this type of work are critically considered.

Particulars are given of the test conditions, and of methods adopted for control of humidity and of atmosphere and regulation of temperature. Consideration was given to the possible effect of creep under test, which is admitted to be a drawback of the wire-test method for measuring rates of oxidation, but it is pointed out that most of the wires tested at temperatures corresponding to service conditions have low creep rates.

The following are among the major observations made and the conclusions drawn:—

The life of wires from two different commercial heats of 80-20 nickel-chromium alloys was found to vary approximately inversely with the humidity of the ambient air; the wire having the longer life appeared to be the more sensitive of the two to moisture.

A graph shows variation with temperature of total life of 80-20 nickel-chromium alloys and iron-chromium alloys containing 20, 26, 16, 12 and 5 per cent. of chromium, all tested in air of 100 per cent. relative humidity at 25°C. The alloys most resistant to oxidation are also most sensitive to changes in temperature, in so far as total life is concerned.

Effect of surface contamination was determined by abrading the wire specimens under water with fine abrasive paper, subsequently dipping them into solutions of various salts, drying, and testing in the usual manner. Treatments with eighteen different salt solutions were applied to 80-20 nickel-chromium and 95-5 iron-chromium wires. The action of the surface salts appears to alter the life of the wires either by influencing the rate of oxidation, or by affecting adherence of the oxide to the parent metal during the heating cycles. The authors consider that this aspect of the subject merits further study, in view of its practical importance.

As would be anticipated, pre-treatment of wires of chromium-iron and nickel-chromium by exposure to moist hydrogen at 1175°C., producing an oxide film rich in Cr_2O_3, effected marked improvement in total life under standard test conditions. The theory underlying this improvement is discussed, and it is noted that some of the alloys tested, which were of compositions on which the film formed would not be of the Cr_2O_3 type, did not show parallel lengthening of life after the moist hydrogen treatment.

Extrusion of Nickel Alloys and Other Materials: Recent Developments

E. LOEWY: 'Latest Developments in Extrusion of Metals.' *Iron and Steel Engineer*, 1952, vol. 29, Apr., pp. 65-8; disc., pp. 69-70.

The author prefaces his review of recent developments by a concise summary of the essential features of the extrusion process and of the particular problems inherent in extrusion of steels and alloys requiring high temperatures and pressures.

The early history of extrusion is then described, including reference to the first commercial extrusion of nickel and high-nickel alloys, which took place at the works of Messrs. Henry Wiggin and Co., Ltd., Glasgow, in 1928, and the installation, by International Nickel Company, in 1943, of equipment for solid extrusion and extrusion of tubes. Experience in the use of the INCO presses, when working nickel, Monel and Inconel, is briefly recorded.

The most important recent advance in relation to

extrusion is the development of the Ugine-Séjournet process (*see following abstract*), by which tool life is being appreciably lengthened and the quality of the extruded product considerably improved. The introduction of salt-bath heating has also been a major factor in recent progress: this method is employed, for example, in the Ugine-Séjournet process, for heating the billets to temperatures up to 2300°F. (1260°C.) prior to application of the glass lubricant.

References are also made to economies in material and improvements in product which have been effected by introduction of the extrusion method for making hollow propellers, which were previously produced by welding, brazing and forming nickel-chromium-molybdenum steel specially-processed flat plates. The U.S. Ordnance Department is currently sponsoring a programme of extrusion of nickel-chromium-molybdenum steel gun tubes in various sizes. Some notes are given on the methods which are to be used for this work.

Among other projects now under way are the extrusion of 18-13 chromium-nickel steel tubing, 2·5 in. diameter with wall thickness of approximately $\frac{3}{16}$-in., from 9-in. diameter hollow billets; extrusion of multi-hole aluminium tubes from solid billets, through a spidered eye; production of aluminium tubes with internal fins along their length; extrusion of titanium, molybdenum, zirconium, and beryllium into various shapes; extrusion of Timken 16-25-6 chromium-nickel-molybdenum steel. Recent improvement of equipment and technique has made possible extension of the process in many directions, for example, 'stepped extrusion' by means of multiple die locks, and the extrusion of sections with continuously varying thickness, and some consisting partly of a pre-forged or formed part which is integrally connected with an extruded portion of appreciable length.

Glass Lubricant in Extrusion of Stainless-Steel Tubing: The Ugine-Sejournet Process

'New Method Makes Stainless Extrusion Practical.' *Steel*, 1952, vol. 130, June 2, pp. 92-6.

An account is given of the operation, by Babcock and Wilcox Company, of the first American extrusion press incorporating the Ugine-Séjournet hot-extrusion process, the outstanding feature of which is the use of fibreglass as lubricant. The use of this material, in place of the carbonaceous lubricants previously employed, has had a revolutionary effect on life of the dies and on surface quality of the product. The principles of the process, the Babcock and Wilcox tube-extrusion plant, and the commercial significance of this method, are considered. Stainless steels now being extruded include 18-8 (Types 304 and 321), 25-20 (Type 310), 16-13-3 chromium-nickel-molybdenum, and straight-chromium (Type 446). Pure molybdenum and titanium are also being handled.

Constitution of Nickel-Rich Nickel-Chromium-Titanium Alloys

See abstract on p. 202.

Sub-Zero Notch-Toughness of Nickel-Alloy Steels

See abstract on p. 210.

Effect of Sigma on Mechanical Properties of Austenitic Nickel-Chromium Steel

G. V. SMITH and E. J. DULIS: 'Effect of Sigma on Strength and Ductility of 25 Cr, 20 Ni Steel.' *Amer. Soc. Testing Materials, Preprint* 82, June, 1952; 11 pp.

The steel used in this investigation was the same as had been studied in the authors' previous work on Effect of Prior Treatment on Precipitation of Sigma Phase (*Welding Jnl.*, 1951, vol. 30, Suppl. pp. 385-9; *Nickel Bulletin*, 1951, vol. 24, Nos. 9-10, pp. 204-5). Its composition is given as carbon 0·07, manganese 1·81, phosphorus 0·024, sulphur 0·013, silicon 0·53, copper 0·10, nickel 22·20, chromium 27·24, vanadium 0·01, per cent. It is noted that the nickel and chromium contents are slightly higher than the A.I.S.I. specification limits for Type 310 steel, which are 22 and 26 per cent. max., respectively.

Specimens of this steel, initially cold-worked to some 35 per cent. reduction, were heated at 1700°, 2000° or 2300°F. (926°, 1093° or 1259°C.) for one hour, and water-quenched, and were then exposed for 7500 hours at 1300°F. (704°C.), to promote precipitation of sigma phase. The material thus treated was tested in comparison with unsigmatized steel. It was found that in room-temperature tensile tests made after exposure at all three temperatures the presence of sigma caused increased yield and tensile strength, associated with fall in elongation and reduction of area. Most pronounced loss in ductility resulted from annealing at 2300°F. (1259°C.). The presence or absence of sigma proved more important than difference in grain size. Precipitation of sigma also resulted in severe loss of notch-impact strength within the test-temperature range of −315° to +500°F. (−193° to +260°C.).

Creep-rupture tests at the exposure temperature (1300°F.: 704°C.) showed the presence of sigma to be slightly deleterious to strength, in terms of either the minimum creep rate or stress for rupture in a specified time. The only exception was for very short rupture times or at fast creep rates, in the case of metal initially annealed at 2300°F. (1259°C.). The trend of these results indicates a possibility that, at sufficiently long times of test, the unexposed and exposed alloy may have similar properties. This conclusion is, however, subject to results of further tests.

High-Temperature Properties of Stainless Steels

W. F. SIMMONS and H. C. CROSS: 'Report on the Elevated-Temperature Properties of Stainless Steels.' *Amer. Soc. Testing Materials Special Technical Publn.* 124, issued 1952; 116 pp. (Supplementing Special Technical Publn. 100 issued in 1950: see *Nickel Bulletin*, 1950, vol. 23, Nos. 8-9, p. 163.)

This report contains a compilation of data received in answer to an appeal made by the A.S.T.M.-A.S.M.E. Joint Committee on Effect of Temperature on the Properties of Metals, issued in 1950 to a number of industrial and research organizations, asking for information, previously unpublished, on the properties of cast and wrought austenitic chromium-nickel steels of the following types: 18-8, 18-8-Ti, 18-8-Nb, 18-8-Mo, 18-8-Mo-Nb, 25-12, 25-20, 25-20-Si,

25-20-Nb, 15-35. The names of the twenty-two sources which have contributed data are recorded in the preface to the report.

The information thus supplied has been correlated with other data already held by the Committee, and the result is presented in a series of curves showing tensile strength, 0·2 per cent. offset yield strength, per cent. elongation, per cent. reduction of area, stresses for rupture in 100, 1000, 10,000 and 100,000 hours, and stress for creep rates of 0·0001 and 0·00001 per cent. per hour (1 per cent. in 10,000 and in 100,000 hours). An appendix gives the primary data from which the summary curves were drawn. Data sheets in the appendix also give the chemical compositions, processing data and other pertinent information relative to the steels included in the survey.

The highest temperatures for which data are recorded vary with the materials, running, in some cases, as high as 2400°F. (1315°C.).

Properties, Treatment, and Uses of Stainless-clad Copper

J. KINNEY: 'Stainless-clad Copper for High-Temperature Service.' *Product Engineering*, 1952, vol. 23, Apr., pp. 129-33.

Details are given of the properties of this composite material, which combines the high thermal conductivity of copper with the corrosion-resistance and high-temperature properties of stainless steel. In general, the corrosion-resisting characteristics of the stainless-steel cladding will determine the applications for which the composite product is suitable, but, due to the relatively low melting point of copper (1981°F.: 1080°C.), the clad metal should not be used where the maximum temperature will exceed 1800°F. (980°C.), and if the surface is to be exposed to a corrosive atmosphere the safe working temperature may be considerably lower. Protection of the copper at the cut edges of the sheet can be effected by 'seal welding'. In this process, the edges of the clad metal are pickled, removing the copper in the 'sandwich' back by about $\frac{1}{32}$ in. The stainless-steel edges are then rolled, to pinch them together, and they are afterwards Heliarc-welded. As an alternative method of protection, the copper can be Calorized, thus introducing aluminium, to form an alloy having a high degree of resistance to corrosion and oxidation.

Workability characteristics of stainless-clad copper are generally similar to those of the cladding material, but the copper core tends to confer greater ductility. In shearing and blanking cutting edges must be kept clean and sharp, to prevent dragging. Spinning can be carried out at somewhat higher speeds than can be used for solid stainless steel: grinding and buffing procedure is as for the cladding metal. In order to prevent 'pebbling' or 'orange-peel', annealing between forming operations should be at 1650°F. (900°C.), but where this surface effect is immaterial a temperature of 1800°F. (980°C.) is preferred if the part is to be used under conditions involving long-time exposure to 1200°F. (650°C.) or above. Induction annealing cannot be used, due to the high electrical conductivity of copper. Pickling procedure is identical with that which would be used for the cladding material. Welding conditions must be adjusted to hold copper pick-up within a 4 per cent. limit: suggestions are made for a set-up which will ensure this, and it is recommended that in butt welding, irrespective of the type of cladding being welded, a rod of 80-20 nickel-chromium alloy or of Inconel should be used. Resistance spot or seam welding can be done by the procedures usually employed for the cladding material being handled. The paper includes some curves incorporating data applicable in designing parts of stainless-clad copper.

Influence of Temperature on the Elastic Constants of Austenitic Nickel-Chromium Steels

F. GAROFALO, P. R. MALENOCK and G. V. SMITH: 'The Influence of Temperature on the Elastic Constants of Some Commercial Steels.' *Amer. Soc. Testing Materials, Preprint* 159, June, 1952; 18 pp.

Elastic moduli in tension and shear were determined, at various temperatures between 75° and 1500°F. (23·8° and 815°C.) for 21 different commercial steels, both carbon and alloyed types. With rising temperature both the tensile and shear moduli decrease approximately linearly until a certain temperature is reached beyond which a more rapid decrease is observed: this temperature is 700°, 900° and 1300°F. (370°, 482° and 704°C.) for plain carbon, alloyed ferritic, and austenitic steels, respectively. Poisson's ratio does not change significantly with temperature. The results show good agreement with those reported by other investigators.

The nickel-alloy steels for which data are included were of the following types:—

C %	Ni %	Cr %	Other Elements %
0·06	9·56	18·71	—
0·07	9·84	17·36	Mo 2·55
0·05	11·21	18·21	Ti 0·60
0·08	10·83	18·04	Nb 0·69
0·17	13·24	22·40	—
0·07	22·20	27·24	—

Precipitation-Hardening Austenitic Nickel-Chromium Steels (17-7 PH and 17-4 PH)

G. T. BEDFORD: 'Precipitation-Hardening Stainless Steels Show Advantages over Standard Grades.' *Materials and Methods*, 1952, vol. 35, May, pp. 99-104.

The article gives a detailed account of the properties, in various conditions of heat-treatment, of the precipitation-hardening stainless steels developed by Armco Steel Corporation. Typical compositions of the two grades are given in the table on p. 221.

Particulars are given of the treatments used to produce the six conditions in which 17-7 PH is supplied and the three variants of 17-4 PH: the former is made in sheet, strip, plate, bar and wire, the latter in bar and

Steel	C %	Cr %	Ni %	Al %	Cu %
17-7 PH	0·07	17·00	7·00	1·10	—
17-4 PH	0·04	16·50	3·50	—	3·50

wire only. Properties typical of the materials in the respective conditions are tabulated, including values for room, elevated, and sub-zero temperatures. Recommendations are made as to processing conditions (forging, machining, heat-treatment, de-scaling and pickling, welding, etc.).

Torsional Properties and Poisson's Ratio for Austenitic Nickel-Chromium Steels

C. W. MUHLENBRUCH, V. N. KRIVOBOK and C. R. MAYNE: 'Mechanical Properties in Torsion and Poisson's Ratio for Certain Stainless Steel Alloys.' *Proc. Amer. Soc. Testing Materials*, 1951, vol. 51, pp. 832-52.

Recent developments in jet aircraft and guided missiles have accentuated the need of designers for data on the torsional properties of stainless steels, and for information on the constancy of Poisson's ratio with increasing stress when the stress-strain relationship is non-linear and the material is anisotropic. The reference data presented in this paper are intended to meet this need.

Standard A.I.S.I. stainless steels of the following types were used in the tests: 301, 302, 304, 316, 321 and 347, in the form of sheet and tubing, in annealed and in cold-worked tempers. Results are given in tables and diagrams.

Torque-twist relationships are shown to be non-linear, as are the tensile or compressive stress-strain diagrams. Values for secant shearing modulus of elasticity and a yield strength at a limiting amount of torsional strain are given, as applicable to design problems.

Work-hardening of the steels lowers the modulus in shear and increases shearing yield strength. Poisson's ratio for longitudinal specimens is almost constant with increasing stress up to, and in some cases beyond, the yield strength. For transverse specimens the ratio increases with increasing stress. Harder tempers are found to have higher values for Poisson's ratio than softer tempers.

The authors suggest reasons for the fundamental forms of behaviour demonstrated, basing their explanations on analysis of the stress-strain relationships, susceptibility to work-hardening, and the state of stress present in the material when subjected to axial loading. The results of the tests indicate that the value usually taken for Poisson's ratio, 0·30, may be satisfactory in some cases, but that in others it is in considerable error. A theoretical relationship between Poisson's ratio and secant moduli in tension and shear is presented.

Friction Studies on Nickel and Nickel Alloys

M. B. PETERSON and R. L. JOHNSON: 'Friction and Surface Damage of Several Corrosion-Resistant Materials.' *Nat. Advisory Committee for Aeronautics, R. and M. E51L20*, 1952; 20 pp.

Liquid metals have potential application as heat-transfer media in power plants, but the extremely corrosive nature of most liquid metals at elevated temperatures introduces many critical design problems, one of which is concerned with the selection of materials which will be satisfactory for sliding surfaces, such as bearings for pumps. In this connexion information on the frictional properties, in air, of corrosion-resistant materials is required, and the investigation reported in this paper was designed to amplify the somewhat sparse data available on this subject.

The tests were made at room temperature, under static and extremely-slow-speed friction conditions, using a range of load, with maximum load in most cases sufficiently high to cause appreciable plastic deformation of the surfaces. The materials studied included combinations of stainless steel, Monel, nickel, Inconel, Nichrome, zirconium, tungsten carbide, and carbon steel. Ball-and-plate apparatus used for the tests, mode of preparation of the specimens, and technique of testing, are fully described.

The friction coefficients of the respective materials are shown in the table below.

Surface failure occurred with all metal combinations except with tungsten carbide sliding on bonded tungsten carbide. Nickel used in combination with various

Slider (Ball)	Plate						
	Nickel	S.A.E. 1020 Steel	Nichrome	A.I.S.I. 347 Stainless Steel	Inconel	Zirconium	Bonded Tungsten Carbide
	Friction Coefficient, μ						
Tungsten carbide	0·55	0·36-0·40	—	0·35-0·60	—	0·49	0·20
S.A.E. 1095 steel	0·85	0·79	0·85	0·67	0·79	0·44	0·34
Monel	0·95	0·85	0·78	0·68	0·55	0·48	—
18-8 Stainless steel	0·97	0·80	0·91	0·96	0·65	0·47	—

sliders gave high friction coefficients and severe surface damage. Zirconium, due to its hardness and the formation of a relatively thick oxide film, gave low values. This oxide film was easily ruptured during sliding.

Intergranular Corrosion in Molybdenum-containing Austenitic Steel Heater Tubes

C. A. WORKS: 'A Case History Involving Intergranular Failure of Stainless Steel Heater Tubes.' *Corrosion*, 1952, vol. 8, June, pp. 217-21.

The phenol plant at the Oleum Refinery of the Union Oil Company of California uses a well-known refining process involving the employment of phenol as a solvent for removal of asphaltic constituents from lube oil stocks. This unit was put into operation in 1939 and worked without incident until 1949, when, at the annual inspection, it was found that cracks had developed in some of the 16-13-3 chromium-nickel-molybdenum steel tubes in the fired heater. Metallurgical examination, details of which are given in this paper, showed that carbide precipitation at the grain boundaries had occurred after prolonged service at about 750°F. (400°C.), thus rendering the tubes susceptible to intergranular corrosion.

Since some of the tubes in the heater (approximately two-thirds of the total number involved), although in a susceptible state, had not yet developed cracks, an attempt was made to salvage them by heat-treatment at 1600°F. (870°C.) for 24 hours. On the basis of tests made on representative tubes so treated it was decided to apply the same remedial treatment to all the heater tubes remaining in the 'good' classification. The tubes so 'repaired' have now been operating satisfactorily for two years, in spite of the fact that the unit has been working, during that time, on a naphthenic-base stock which is more corrosive than the type previously used.

Corrosion Reference Data

G. A. NELSON: 'Corrosion Data Survey.' *Shell Development Co., San Francisco, California; Engineering Report* 361, Sept. 1, 1950 (superseding Report 327).

In this compilation an attempt has been made to summarize corrosion-test data in a group of charts which will indicate, to the chemical engineer or other user, which materials may reasonably be considered for service under specified corrosive conditions. It is emphasized that the data are qualitative only, and that in many cases further tests and pilot-plant experience may be required to ensure correct choice of material, but since the charts have been checked against actual plant conditions, and found to give good correlation, they may safely be used as indicating broadly the behaviour likely to be characteristic of given materials under specified conditions.

The range of materials for which information is given is very wide, covering over 50 of the most generally used ferrous and non-ferrous materials, three plastic materials, and carbon. Typical compositions of the metals, steels, and alloys are given.

Forty charts list corrosive reagents alphabetically, and show the behaviour typical of the respective materials in them: these are supplemented by charts dealing more specifically with resistance to sulphuric and hydrochloric acids, and to mixed acids. Other charts cover operating limits for carbon and alloy steels in contact with hydrogen at high temperatures and pressures, and corrosion of metals by carbon monoxide at high pressure, in presence of hydrogen.

The charted data are preceded by a concise note on some of the main sources from which the information has been drawn, and by a brief discussion of the methods which have been adopted with regard to choice of materials for which data are presented, and methods of showing concentration, temperature, and rate of corrosion on the charts. It is conceded that in the mode of presentation adopted it is impossible to do justice to the influence of various other factors which vitally affect corrosion. Some attempt has been made, however, to embody information on liability to stress cracking, though it is admitted that in this case the data are sparse.

The report has been issued by its compilers to a number of companies and corrosion laboratories for comments, and some of the constructive suggestions received from these sources have been embodied in this edition. Certain major comments are included as a supplement to the reference charts.

Atmospheric Corrosion-Resistance of Low-Alloy Nickel-containing Steels

H. R. COPSON: 'Atmospheric Corrosion of Low-Alloy Steels.' *Amer. Soc. Testing Materials, Preprint* 70, June, 1952; 22 pp.

In 1941 five sets of seventy-one low-alloy steels were placed on exposure test in the industrial atmosphere of Bayonne, N.J., and in the marine atmosphere at Block Island, R.I. Results of examination of sets of specimens removed at intervals since that date have already been published (*Proc. Amer. Soc. Testing Materials*, 1945, vol. 45, p. 554 and 1948, vol. 48, p. 591). The present paper records complete results for the 9-year period: it includes details of weight losses, depths of pitting, thickness measurements, calculated pitting factors, and weight of rust found on the specimens.

For full details of the conditions of exposure and the compositions of the steels undergoing test, reference is directed to the two earlier reports, but a summary of the main constituents of the respective groups of specimens is made in this paper. The materials for which data are presented cover the following types of material: high-purity iron + copper: low-phosphorus steel + copper; high-phosphorus steel + copper; high-manganese and high-silicon steels + copper; copper steel containing chromium and silicon; copper-molybdenum steels; nickel steels; nickel-chromium steels; nickel-chromium-molybdenum steels; nickel-copper steels; nickel-copper steels containing chromium; nickel-copper steels containing molybdenum.

The following conclusions are drawn from correlation of results from all forms of examination to which the specimens were subjected (see above).

'Even after the 9-year exposure the lowering of the surface level of the specimens was only 1 mil. or less

for all the better steels. Most of the attack occurred in pits, and the depth of the pits was important. Depth of pit did not rate the steels in the same order as weight losses: for example, steels containing chromium tended to have fewer but deeper pits, and steels containing nickel tended to show more pits, but of shallower depth.

'Alloying decreased both pit depth and the number of pits, but the beneficial effect of alloying was more marked in decreasing weight losses than in lessening pit depths. The new data recorded confirmed the beneficial effect (reported earlier) of fractional percentages of copper, of small amounts of phosphorus, and of one per cent. or more of nickel. Nickel additions produced low initial weight losses, and on long exposure nickel was particularly effective in decreasing pit depths. Chromium was particularly effective in flattening weight-loss/time curves. Chromium and copper additions to complex steels were more helpful in the industrial atmosphere, and manganese in the marine atmosphere.

'The flattening of the weight-loss/time curves resulted in some remarkably low corrosion rates. From the fifth to the ninth year rates below 1 m.d.d. were fairly common. This flattening effect was more pronounced in the industrial than in the marine atmosphere. At the 9-year stage corrosion was much less severe at the former than at the latter station. Pit depths continued to deepen with time at Block Island, whereas at Bayonne pits were scarcely any deeper at nine than at five years.

'All the time curves continued to diverge, indicating that the benefit of alloying increased with time. Weather controls showed that weather conditions from 1941 to 1950 (i.e., over the whole period) had no significant effect on the results, but conditions near the start of exposure have a lasting influence, and it is recommended that in exposure tests started at different times controls should be included, to facilitate comparisons.'

Resistance of Stainless Steel to Weed and Insect Sprays

J. J. PATERSON and G. L. SHANKS: 'The Effects of Weed and Insect Sprays on Spraying Equipment Materials.' *Manitoba Dept. of Agriculture and Immigration, Winnipeg, Canada; Publn.* 249, Oct., 1951; 16 pp.

The report gives detailed results of tests in which 24 different materials, metallic and non-metallic, were subjected to the action of 6 spray solutions, and of tap water. The metallic materials exposed included iron and steel, galvanized sheet, zinc, tinned iron, copper, brass, aluminium, and stainless steel: various metals carrying non-metallic coatings were also tested.

The results show that only two materials were immune from attack in all the solutions used: these were stainless steel and a non-metallic finish designated Kromer's Finish 'X'. Recommendations are made with regard to selection of various materials which may be used in some of the mixtures, and suggestions are put forward for maintenance measures which will prolong the life of equipment handling sprays.

Production and Processing of Steel: Handbook

See abstract on p. 209.

Shot-Blast Cleaning of Stainless-Steel Strip

J. B. DELANEY: 'Shot Blasting Speeds Stainless Strip Cleaning.' *Iron Age*, 1952, vol. 169, June 19, pp. 133-5.

The article describes the shot-blasting plant which has been installed by Allegheny Ludlum Steel Corporation as part of the cleaning cycle for all grades of stainless steel. Introduction of the Wheelabrator unit into the cleaning line has effected marked economies in cost and manpower, and has improved the quality of the product. Coils weighing 15,000-16,000 lbs. are easily handled: at strip speeds of 30-75 f.p.m., depending on width of strip being treated, 6 tons per hour can be cleaned. A drawing shows layout of the cleaning plant, indicating progress of strip from uncoiler, through cleaning machine, and pickling solutions, to re-coiling.

Nickel-Chromium Stainless-Steel Tubing

TECHNICAL DIVISION, SUPERIOR TUBE COMPANY: 'Use of Needle Tubing Extended to Mechanical Applications.' *Materials and Methods*, 1952, vol. 35, June, pp. 106-8.

Chromium-nickel steel tubing, of the 18-8 (Type 304) grade, has for some years past been in extensive use for hypodermic needles, for which it is supplied in a specially hard-drawn temper developed to ensure a high level of stiffness combined with a fair degree of ductility. A recent expansion in the use of this tubing in the surgical field is in radon implanters employed in the treatment of malignant tissues. Many uses of a non-surgical nature are also developing for fine stainless-steel tubing, e.g., for application of minute quantities of lubricant to delicate instruments, for dispensing of small amounts of liquids in microchemical work, and in X-ray collimating tubes. Small-diameter tubing is also being used in pitot tubes and manometer lines in laboratory equipment, in gramophone pick-ups and in automatic electrical ampoule filling machines.

This article contains practical recommendations on the handling of needle tubing, designed to ensure optimum results with maximum economy.

Welding of Heat-Resisting Nickel-Chromium Steels

H. F. TREMLETT: 'Welding of Heat-Resistant Steels.' *Welding and Metal Fabrication*, 1952, vol. 20, July and Aug., pp. 258-61, 299-303.

The paper is based on a lecture delivered at the 1951 Summer School organized by The British Welding Research Association.

Part I comprises an introductory discussion on resistance to scaling, and the mechanism of scaling, followed by consideration of the outstanding importance of chromium as a constituent of oxidation-resisting alloys. The influence of silicon, nickel, tungsten and molybdenum, on the scaling-resistance and high-temperature strength of heat-resisting steels, is then reviewed.

In Part II the author deals with (1) the distinctive

features of chromium and chromium-nickel-(tungsten) heat-resisting steels which affect their suitability for fabrication or repair by welding, (2) distinctive features of behaviour of the various grades during high-temperature service, and (3) procedure for welding the respective types, with particular reference to precautions required in order to achieve and preserve individual properties essential for satisfactory high-temperature service.

X-Ray Fluorescent Analysis of Nickel and Nickel Alloys

See abstract on p. 199.

Knife-Line Intergranular Corrosion in Welded Austenitic Nickel-Chromium Steels

M. L. HOLZWORTH, F. H. BECK and M. G. FONTANA: The Mechanism of Knife-Line Attack in Welded Type 347 Stainless Steel.' *Corrosion*, 1952, vol. 8, June, pp.222-3.

Discussion, by J. J. HEGER, on paper published *ibid.*, 1951, vol. 7, Dec., pp. 441-9; *Nickel Bulletin*, 1952, vol. 25, No. 3, p. 87, and authors' reply. Heger emphasized that greater prominence should be given to the finding that only when low stress-relieving temperatures are applied does Type 347 steel show susceptibility to knife-line corrosion. In reply, the authors present additional data on the influence of temperature of stress-relief treatment on susceptibility to knife-line attack. They conclude that in cases where stress-relief is necessary the temperature of treatment should be at least 1500°F. (815°C.), and preferably higher. Treatment at 1650°F. (900°C.) produces precipitation of niobium carbides, thus preventing knife-line attack even when the specimen is subsequently subjected to sensitizing treatment. Even relatively short times at this temperature are effective, since niobium carbides form very rapidly.

Welded Austenitic Nickel-Chromium Steel Piping for High-Temperature Use

AMER. SOC. TESTING MATERIALS: 'Proposed Tentative Specification for Electrically Fusion-Welded Austenitic Chromium-Nickel Alloy Steel Pipe for High Temperature Service.' Contained in Report of Committee A-1 on Steel; *A.S.T.M. Preprint* 2, June, 1952, pp. 37-41.

The specification covers piping of four grades of steel, Types 304, 316, 347 and 321, all of which materials are governed, in plate form, by A.S.T.M. specification A-240. Tensile and bend properties, hydrostatic tests, and finish are among the requirements included.

Corrigendum
Complex Austenitic Nickel-Chromium Creep-Resisting Steels

Brit. Pat. 668,889: *Nickel Bulletin*, 1952, vol. 25, No. 7, p. 187. In preferred composition for 'copper 10·0' please read 'cobalt 10·0'.

Attention is drawn to the fact that many of the names of materials mentioned in The Nickel Bulletin are *Registered Trade Marks.*

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